BENTHIC AND SEDIMENTOLOGICAL STUDIES OF THE GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE[1]

by

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Introduction

The Georgetown Ocean Dredged Material Disposal Site (DMDS) has been selected by the Corps of Engineers for release of sediments dredged from the channels associated with Georgetown Harbor. This disposal area is similar in depth and bottom type to the larger Charleston Harbor Ocean Disposal Area located approximately 87 km to the southwest. Although the latter area was sampled in 1978 for a baseline benthic and sedimentological characterization (South Carolina Wildlife and Marine Resources Department, 1979), no similar data base exists for the Georgetown DMDS. At the present time, the Georgetown DMDS is being used under iterim approval by the Environmental Protection Agency (EPA). Continued use of this site requires more baseline information for final EPA site approval as authorized by the Marine Protection Research and Sanctuaries Act (MPRSA). To obtain the necessary data, the Corps contracted with the South Carolina Wildlife and Marine Resources Department (SCWMRD) to conduct benthic and sedimentological studies in and near the Georgetown DMDS. Specific objectives of this study were to:

1) Provide a review of existing information on the physical, chemical and biological conditions in the vicinity of the Georgetown DMDS and provide a succinct description of biological, recreational, or other resources that might be affected by ocean disposal;

2) Describe the mineralogical, textural, and chemical characteristics of the bottom sediments in the Georgetown DMDS, in a control site, in three stations "down current" of the DMDS, and in the navigation channel;

3) Describe the sediment bedforms present in the Georgetown DMDS, in the control area and in the three "down current" stations with regard to their size, orientation, and composition.

4) Ascertain whether the sediment characteristics of the DMDS and the stations "down current" have been altered by current disposal practices;

5) Describe temperature-depth, salinity-depth, and dissolved oxygen-depth profiles in the water column at all stations, and determine concentrations of metals, pesticides, PCB's, high molecular weight hydrocarbons, and the turbidities at four stations (one DMDS station, one control station, one "down current" station, and one entrance channel station);

6) Characterize the species composition and density of benthic communities in the DMDS, in the control site, and in the "down current" stations;

7) Determine the degree of bioaccumulation of pollutants in selected sedentary benthic organisms collected from the DMDS, control site, and "down current" stations;

8) Assess the effects of the present dredged material disposal practices on bottom communities in the DMDS and the three "down current" stations.

Results presented in this report provide baseline data necessary for appraising the effects of deposition of dredged material in the Georgetown ocean disposal area. The study also supplements existing knowledge of the physical, chemical, and biological characteristics of the nearshore sand bottom habitat off South Carolina.

Review of Existing Information

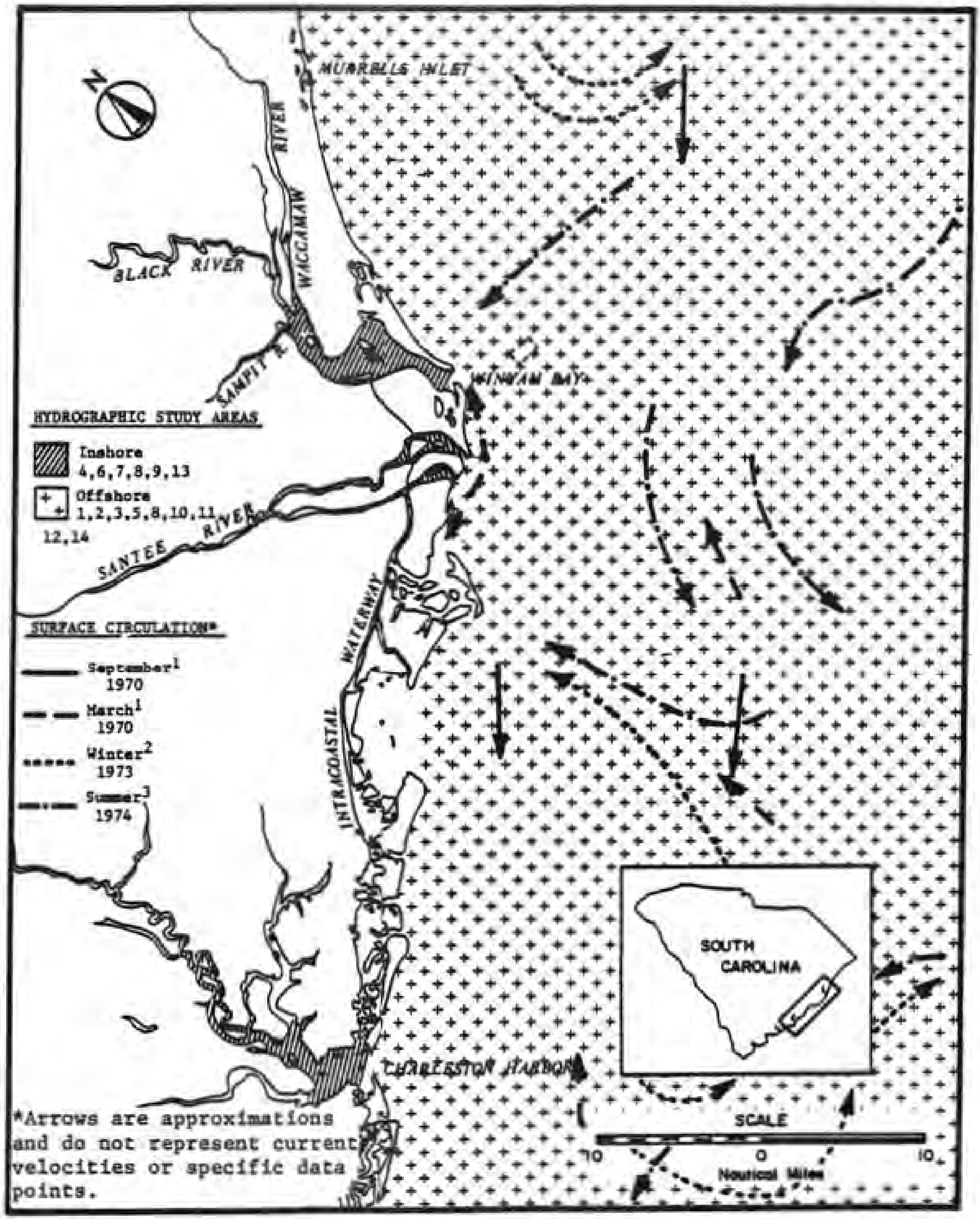
The following survey of existing information is intended to provide a brief description of the environmental conditions and biological resources near the Georgetown DMDS. This information is compared with that described by the US EPA (1982) for similar disposal sites within the South Atlantic Bight.

ENVIRONMENTAL AND BIOLOGICAL CHARACTERISTICS

Hydrography and Currents

A summary of previous studies which provide hydrographic data in the vicinity of the Georgetown DMDS is presented in Figure 1. Although most of these studies sampled areas either inshore or offshore of the proposed DMDS, the data generally support conditions described by the US EPA (1982) for nearshore South Carolina waters.

Surface water temperatures in the nearshore areas around Winyah Bay are usually within the seasonal variation of 10-25°C noted in surveys near Savannah, Charleston, and Wilmington (US EPA, 1982), although temperatures have been noted which exceed those extremes. For example, Mathews and Pashuk (1977, 1982) noted surface temperatures from < 11-32°C in nearshore South



*Arrows are approximations and do not represent current velocities or specific data points.

Figure 1. Location of hydrographic study areas and surface circulation patterns: ^{1}Bureau of Land Management (BLM), 1981; ^{2}Mathews and Pashuk, 1977; ^{3}Mathews and Pashuk, 1982; ^{4}Allen, et al., 1982; ^{5}Churgin and Halminski, 1974; ^{6}Hinde, et al., 1981; ^{7}Johnson, 1970; ^{8}Jones, Edmunds and Assoc., 1979a, 1979b, 1979c; ^{9}Mathews et al., 1981; ^{10}Minerals Management Service (MMS), 1982; ^{11}Science Applications Inc. (SAI), 1981a, 1981b; ^{12}SAI, 1983a, 1983b; ^{13}Shealy, 1974; ^{14}South Carolina Wildlife and Marine Resources Dept., 1979.

Carolina waters during four sampling periods of 1973 (Feb. - Nov.), but during 1974 (May - Nov.), temperatures varied from 18-27.5°C. Churgin and Halminski (1974) also presented water temperature data collected over a 50-year period from inshore and offshore waters of the region (32-34°N, 75-81°W) and noted surface temperatures of 10.9-29.3°C. Just inshore of the Georgetown DMDS, Allen et al. (1982) collected samples from Winyah Bay and observed surface temperatures ranging from 6.0-30.7°C at their station near the mouth of the Bay. Similarly, surface temperatures ranging from 11.0-29.8°C were noted in the mouth of the North Santee River (Mathews et al., 1981). Water temperatures in nearshore areas are primarily influenced by air temperature and river runoff.

The salinity and turbidity of water in the vicinity of the Georgetown DMDS is greatly influenced by waters from Winyah Bay and, to some extent, by waters from the Santee Rivers. Figure 2 clearly shows the influence of Winyah Bay waters with respect to turbidity and sediment loads. Obviously, waters from Winyah Bay are also influencing the salinity and temperature in the area of the DMDS. In the mouth of Winyah Bay, Allen et al. (1982) noted salinities ranging from 27.2-35.2 ^{o}/oo and never recorded secchi disc readings greater than 0.65 m. At a nearby location in the Bay, Mathews and Shealy (1982) observed extremely low salinities (< 2 ^{o}/oo). Similarly, in the mouth of the North Santee, Mathews et al. (1981) noted salinities from 0.2-32.9 ^{o}/oo and secchi disc readings which never exceeded 0.8 m. Further offshore, Mathews and Pashuk (1977, 1982) observed surface salinities which ranged from 32.5-34 ^{o}/oo in 1973 and 34-35 ^{o}/oo in 1974. Finally, over the 50-year period evaluated by Churgin and Halminski (1974), surface salinities in nearshore and offshore waters ranged from 31.9-35.9 ^{o}/oo.

Due to the shallow depths in the Georgetown DMDS and its proximity to Winyah Bay and the Santee Rivers, vertical stratification of salinities in the area is dependent on tidal stage, wind disturbance and the amount of fresh water runoff. After the scheduled rediversion of water flow from the Cooper River to the Santee Rivers, the hydrographic regime and vertical stratification in the area of the Georgetown DMDS may be considerably altered.

Current patterns in the vicinity of the Georgetown DMDS have not been well studied. Generally, longshore and nearshore currents run in a southerly direction along the South Carolina coast, although inshore currents become less well defined in the fall (Mathews and Pashuk, 1977). The strong tidal currents in Winyah Bay also have an influence on water flow in the area of the Georgetown DMDS. Generally, factors considered most important in influencing inner-shelf circulation patterns are wind and water density (Science Applications, Inc., 1983).

Wave energy is moderate along the South Carolina coast because waters are relatively shallow for a considerable distance offshore. Waves less than 4 ft. are observed 55% of the time and waves greater than 12 ft. are observed only 2% of the time (MMS, 1983).

Bottom Sediments

Sediments in the nearshore area around Winyah Bay have not been well studied, but shelf sediments in this region appear to be primarily represented by medium- to coarse-grained sands (Pilkey et al., 1979; MMS, 1983). A summary of sedimentological conditions on the shelf off South Carolina is provided in Figure 3. In the entrance channel of Winyah Bay, Hinde et al. (1981) obtained limited information on sediments at three stations just outside the jetties. Two of the stations sampled in that study (CW01 and CW02) were mostly medium to coarse sands (> 90%) and the third station (CW03) was mostly silty clays.

With respect to sediment transport, Mathews et al. (1980) indicated that the north jetty of the Winyah Bay entrance channel traps the southerly littoral drift of sediments, resulting in deposition at the southern end of North Island. They also indicated that the original Winyah Bay ebb-tidal delta has largely been destroyed since completion of the south jetty. Stapor (1978) noted that between 1925 and 1964 South Island experienced a net deposition rate of 70,000 m^{3}/yr. from onshore movement of sand under the influence of waves and tidal currents. If similar deposition patterns are occurring presently, it is possible that sediments disposed in the DMDS would move shoreward towards South Island. Additionally, some disposal sediments could also move back into the bay channels due to very strong tidal currents. Because of the shallow bottom depths in the Georgetown DMDS ($\simeq$ 6-11 m) and the proximity of this area to the entrance channel, wave action and tidal currents should be the primary factors influencing sediment distribution. Detailed bathymetric surveys in the area show no clear evidence of sediment mounding as a result of past disposal activities (see Figure 4 for a plot of an April 1983 survey).

Chemistry and Pollutants

Dissolved oxygen in nearshore and offshore waters off South Carolina were recorded over a 50-year period by Churgin and Halminski (1974). Values ranged from 3.8-6.1 ml/l, with highest average concentrations observed during the winter and lowest average concentrations observed in the summer. Near Winyah Bay, the dissolved oxygen in surface coastal waters ranged from < 4.0 ml/l to 6.5 ml/l during 1973-1974 with similar seasonal trends in concentrations (Mathews and Pashuk, 1977, 1982).

Nutrient input to the Georgetown DMDS area may be strongly influenced by waters from Winyah Bay. Although no seasonal data could be found for waters at the Bay entrance, Allen et al. (1982) collected samples at two stations in Winyah Bay and noted a bimodal pattern of nitrate and nitrite concentrations. Highest values were observed in late fall, winter, and spring; lowest values were noted in summer. Allen et al. (1982) also measured phosphorous

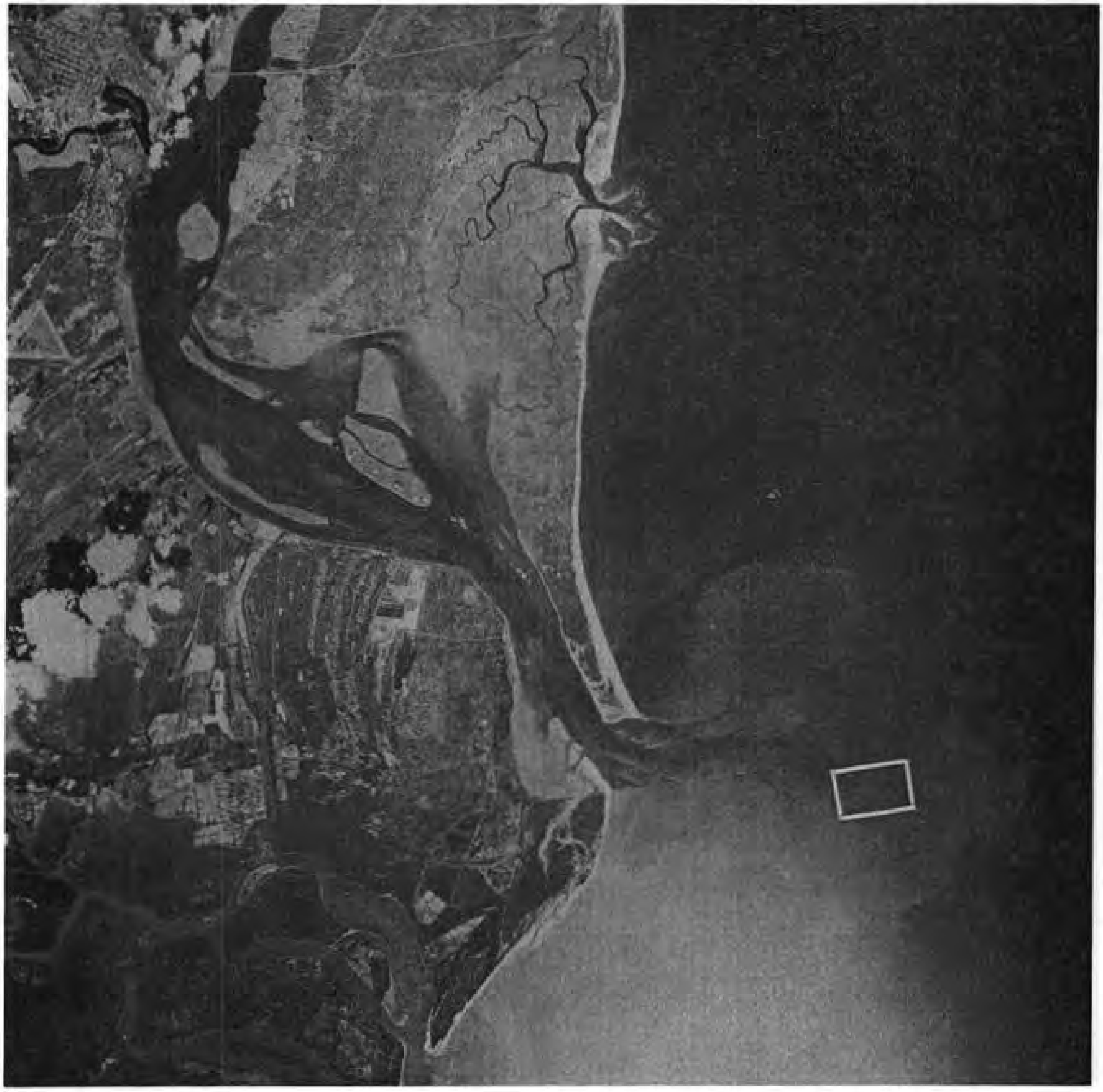


Figure 2. Landsat photograph of Winyah Bay and nearshore coastal waters. Note the large plume of turbid water which encompasses the DMDS area. Lighter area at bottom of photograph is reflection of the sun.

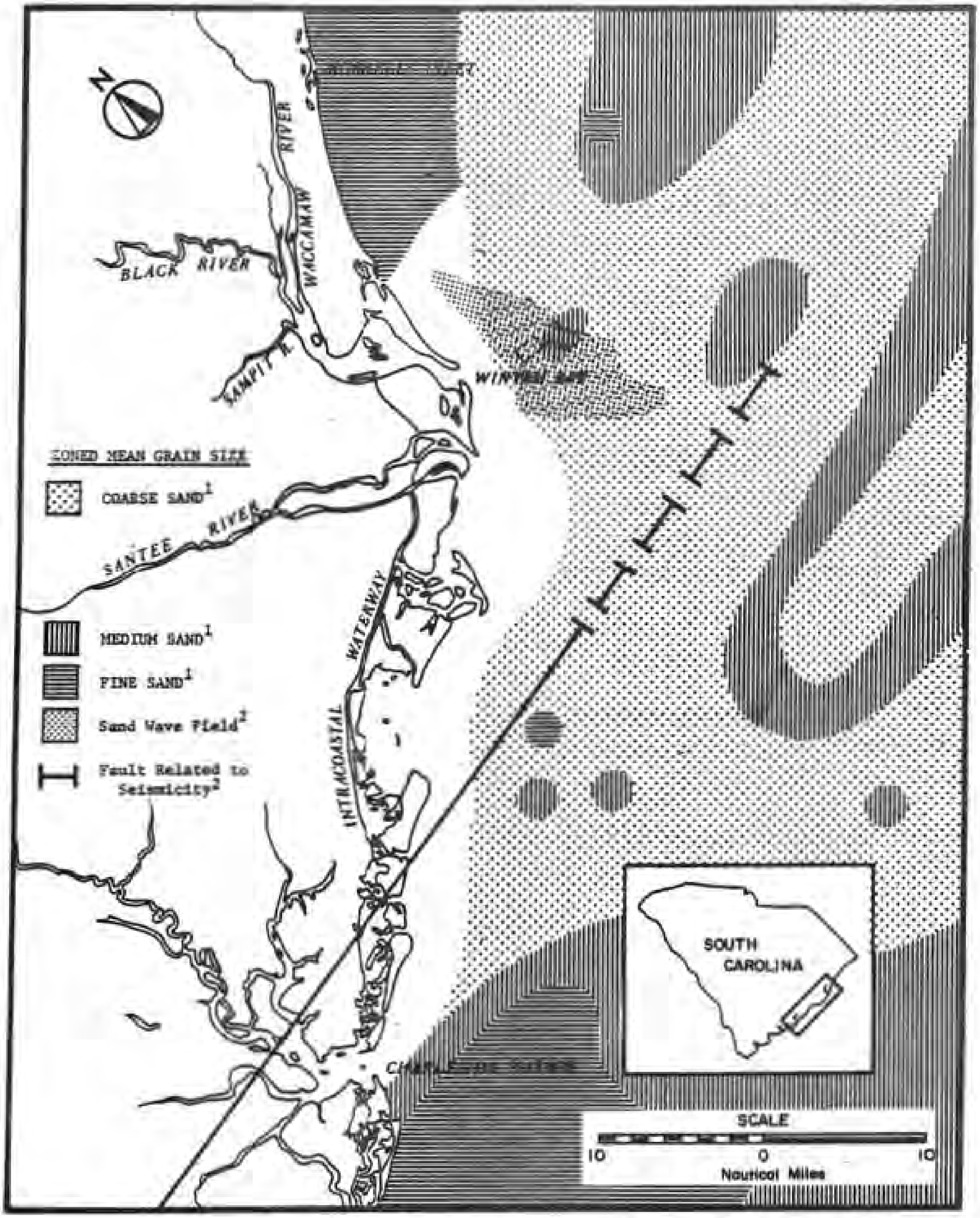


Figure 3. Areal distribution of mean grain size: ^{1}Pilkey et al., 1979; ^{2}MMS, 1983.

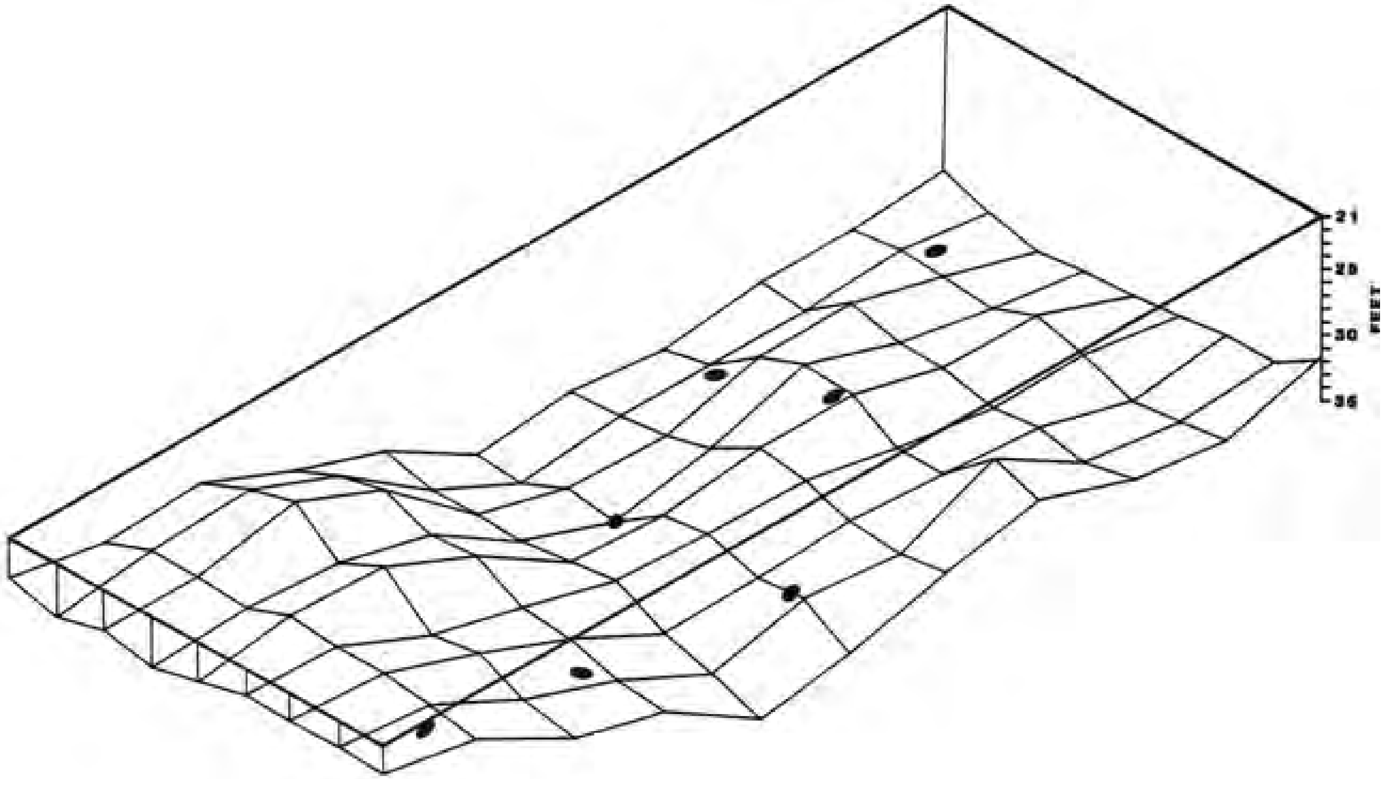


Figure *4*. Three-dimensional plot of bottom survey data collected in the Georgetown DMDS by the U.S. Army Corps of Engineers, April 1983. Rectangular boundaries represent the DMDS boundaries and dots represent the stations sampled during winter and summer in the present study. The vertical scale is greatly exaggerated relative to the horizontal scale.

levels and noted highest concentrations in summer and early fall and lowest concentrations in winter.

Jones, Edmunds and Associates, Inc. (1979c) measured concentrations of nutrients, trace metals, and organic pollutants in waters from the Georgetown DMDS, as well as from four stations in the entrance channel. They did not detect any pesticides or PCBs in their samples, nor did they observe high concentrations of nutrients or trace metals among the samples tested. However, they did measure cadmium concentration in DMDS waters which was 22 times the limiting permissible concentration.

Bed sediments in Winyah Bay were analyzed for trace metals and pesticides by Johnson (1970). He concluded that Winyah Bay is relatively unpolluted by pesticides, although he found some trace metals. Sediments in the Georgetown DMDS have not been analyzed for pesticides or trace metals prior to the present study, but Van Dolah et al. (1983) noted only low concentrations of metals and nutrients in sediments collected from the Charleston DMDS.

Biology

Phytoplankton and zooplankton communities have not been well studied in the nearshore coastal waters of South Carolina. The limited data available for these planktonic groups is best summarized by Sandifer et al. (1980). In Winyah Bay, Allen et al. (1982) examined chlorophyll concentrations and noted highest values in summer months (July - Sept.). Just north of Winyah Bay, Lonsdale and Coull (1977) examined the seasonal composition of zooplankton communities in North Inlet. They noted that copepods dominated the community (66-69% of total density) with the most abundant species being Parvocalanus crassirostris, Acartia tonsa, Oithona colcarva, and Euterpina acutifrons. The US EPA (1982) also notes that inshore waters are dominated by copepods.

The potential effects of offshore disposal on plankton communities around the Georgetown DMDS cannot be easily defined, but it is likely that increased turbidities from disposal operations would have some localized impacts. Of most concern are the nauplii of certain species of shrimp (Penaeus setiferus, P. aztecus) and larval ichthyofauna. Short-term disposal of sand sediments should not have an enduring impact on these taxa, but longer-term disposal or disposal of silts and clays might be more severe in their effects.

Benthic communities are probably the best biological indicators of disposal impacts because most infaunal species comprising those communities are relatively sedentary. Benthic communities inhabiting sand bottom areas of shallow coastal waters have been examined in the Charleston DMDS (US EPA, 1982; Van Dolah et al., 1983) and at Murrells Inlet (Knott et al., 1983a, 1983b). Limited samples were also collected in the entrance channel to Winyah Bay just outside the jetties (Hinde et al., 1981). Relatively diverse infaunal assemblages were noted in all areas, with polychaetes generally dominating the communities. Abundant infaunal species in the Charleston DMDS area included the cephalochordate Branchiostoma caribaeum; the sipunculid Aspidosiphon spinalis; the polychaetes Spiophanes bombyx, Goniadides carolinae, Spio pettiboneae, Nephtys picta and Prionospio cristata; the lunulitiform bryozoan Cupuladria doma; the amphipod Rhepoxynius epistomus; and nematodes (Van Dolah et al., 1983). At Murrells Inlet, the abundant subtidal infauna were the polychaetes S. bombyx, Scolelepis squamata and Podarke obscura; the amphipods Protohaustorius deichmannae, Acanthohaustorius millsi, and Platyischnopidae; the bivalves Tellina sp., Crassinella martinicensis and Donax variabilis; and nematodes (Knott et al., 1983b). In the entrance channel to Georgetown Harbor, the bivalves Mulinia lateralis and Crassinella lunulata and the polychaetes P. cristata and Paraprionospio pinnata were most abundant (Hinde et al., 1981).

Sessile benthic invertebrates commonly found in the Charleston DMDS included the hydroid Clytia cylindrica; the bryozoans Membranipora tenuis, Microporella ciliata and Parasmittina nitida; and the barnacle Balanus venustus. Most of the these sessile species were attached to large shells, and other firm substrata. The bivalve Chama macerophylla and the sand dollar Mellita quinquiesperforata were also prevalent in this DMDS, with M. quinquiesperforata being most common in finer sediments (Van Dolah et al., 1983).

In the entrance channel to Georgetown Harbor, sand dollars (M. quinquiesperforata) were the most abundant large invertebrates collected by dredge, whereas shrimp (Penaeus setiferus, P. aztecus) and blue crabs (Callinectes sapidus) were the most abundant invertebrates caught by trawl (Hinde et al., 1981). Wenner et al. (1981) also found these decapod crustaceans to be numerically dominant in their study of Winyah Bay.

No long-term effects of disposal on benthic communities have been detected in the Charleston DMDS, primarily due to the similarity of dredged material to the existing sediments in the disposal area (Van Dolah et al., 1983). Data on benthic communities present in the Georgetown DMDS were lacking prior to the present study.

Demersal fish communities associated with sand bottom habitat in South Carolina coastal waters have been examined by Wenner and Barans (1980). Dominant species in the 9-18 m depth zone included southern porgy (Stenotomus aculeatus), sea cat (Arius felis), sand perch (Diplectrum formosum), lizard fish (Synodus foetens) and spot (Leiostomus xanthurus). Abundant fishes caught in the Winyah Bay estuarine system by Wenner et al. (1981) and Allen et al. (1982) included Atlantic menhaden (Brevoortia tyrannus), silver perch (Bairdiella chrysura), bay anchovy (Anchoa mitchilli), star drum (Stellifer lanceolatus), weakfish (Cynoscion regalis), spot (L. xanthurus), white catfish

(*Ictalurus catus*), Atlantic croaker (*Micropogonias undulatus*), hog choker (*Trinectes maculatus*) and tonguefish (*Symphurus plagiusa*). Hinde et al. (1981) also collected these species and numerous others.

Biological data collected from the above studies generally support the information presented by the US EPA (1982) for the South Atlantic Bight. However, exceptions are noted with respect to infaunal assemblages (see Results and Discussion).

LOCATION IN RELATION TO LIVING AND NON-LIVING RESOURCES

Fisheries and Shellfish Grounds

Commercially and recreationally important species found in the estuarine and coastal marine areas around Winyah Bay include shrimp (*Penaeus setiferus*, *P. aztecus*), blue crabs (*Callinectes sapidus*), oysters (*Crassostrea virginica*), clams (*Mercenaria mercenaria*), Atlantic sturgeon (*Acipenser oxyrhynchus*) and other finfish species such as black sea bass (*Centropristis striata*), porgy (*Pagrus pagrus*, *Calamus leucosteus*), grouper (*Mycteroperca microlepis*, *M. phenax*), red snapper (*Lutjanus campechanus*), mackerel (*Scomberomorus cavalla*) and many others. The general location of these fisheries is summarized in Figure 5.

Commercial shrimping occurs primarily within 3 miles of shore; however, around the entrance to Winyah Bay shrimpers often work further offshore (3-5 mi.). In South Carolina, shrimping occurs from May through December with peak catches in September and October. Incidental catches from the shrimp fishery are also economically important and include many finfish species (Keiser, 1977). Shrimp populations in the area around the disposal site might decline during periods of disposal due to the associated increased turbidity; however, the effects of offshore disposal of dredged materials on shrimp populations have not been adequately studied.

The mollusk fisheries are also seasonal, beginning in September and ending in May. In Georgetown County, clam landings were of much greater economic value than oyster landings during 1982 (SCWMRD, unpubl. data). Clam harvesting in the Santee estuary increased considerably after the introduction of hydraulic harvesting in 1974 (McKenzie et al., 1980). The scheduled rediversion of waters from the Cooper River estuary, however, is expected to largely destroy shellfish grounds in the Santee estuary. Disposal of offshore channel sediments in the Georgetown DMDS will probably not have much effect on the inshore shellfish grounds, since they are not close to the DMDS (Figure 5).

The amount of blue crabs caught in Georgetown County was greater during spring, summer and fall months than during winter, with greatest catches during March of 1982 (SCWMRD, unpubl. data). As noted for clam and oyster beds, it is unlikely that the blue crab fishery in the Winyah Bay and Santee River estuaries will be influenced by offshore disposal of sand sediments.

Commercial finfish landings in Georgetown County totaled more than two million pounds (SCWMRD, unpubl. data). As noted earlier, many of the fishes landed include black sea bass, grouper, snapper, porgy and other reef fishes. These fishes are associated primarily with offshore hard bottom reef habitats, which have not been found near the Georgetown DMDS.

Winyah Bay is the location of the biggest Atlantic sturgeon fishery in the Sea Islands coastal region (McKenzie et al., 1980) and almost 50,000 lbs. of sturgeon were landed in Georgetown County during 1982 (SCWMRD, unpubl. data). These fish are generally caught with nets set in the ocean near the jetties. Due to the proximity of this fishery to the Georgetown DMDS, there is the possibility of negative effects if disposal activities take place when sturgeon are abundant near the DMDS. Although specific effects of disposal operations on sturgeon populations have not been documented, Morton (1977) noted mortality and displacement of other fishes resulting from increased turbidity. Leland (1968) indicates that sturgeon gather at the inlets during February and March and then move up the inlets as temperatures rise. The fishing season around the jetties begins 15 February and ends 15 April, although sturgeon are still in the area after that date (Smith et al., 1982; SCWMRD, unpubl. data). Most sturgeon landings in Georgetown County occurred from February to June during 1982, with peak landings occurring during March and April. Negative impacts on the sturgeon fishery could be minimized if disposal operations are avoided during the period from mid-February through May.

Recreational finfish catches are primarily from head-boat charters to offshore reefs, fishing on private boats for reef fish and large pelagic species, and pier fishing. Most recreational finfish catches would not be influenced by disposal activities in the Georgetown DMDS

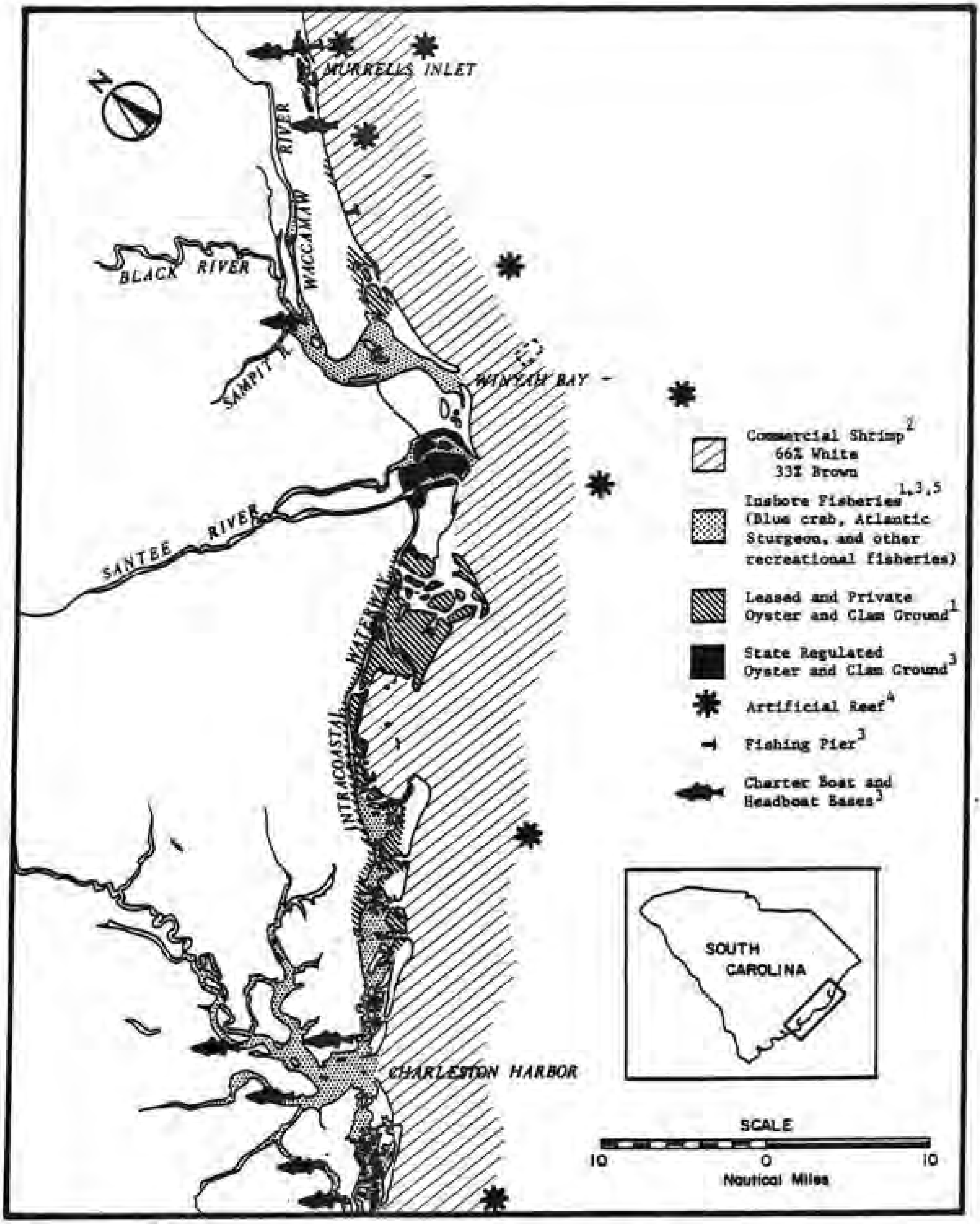


Figure 5. Location of commercial and recreational fisheries resources: [1]Davis, et al., 1980; [2]BLM, 1981; [3]Moore, 1980; [4]Myatt, 1978; [5]Smith, 1983.

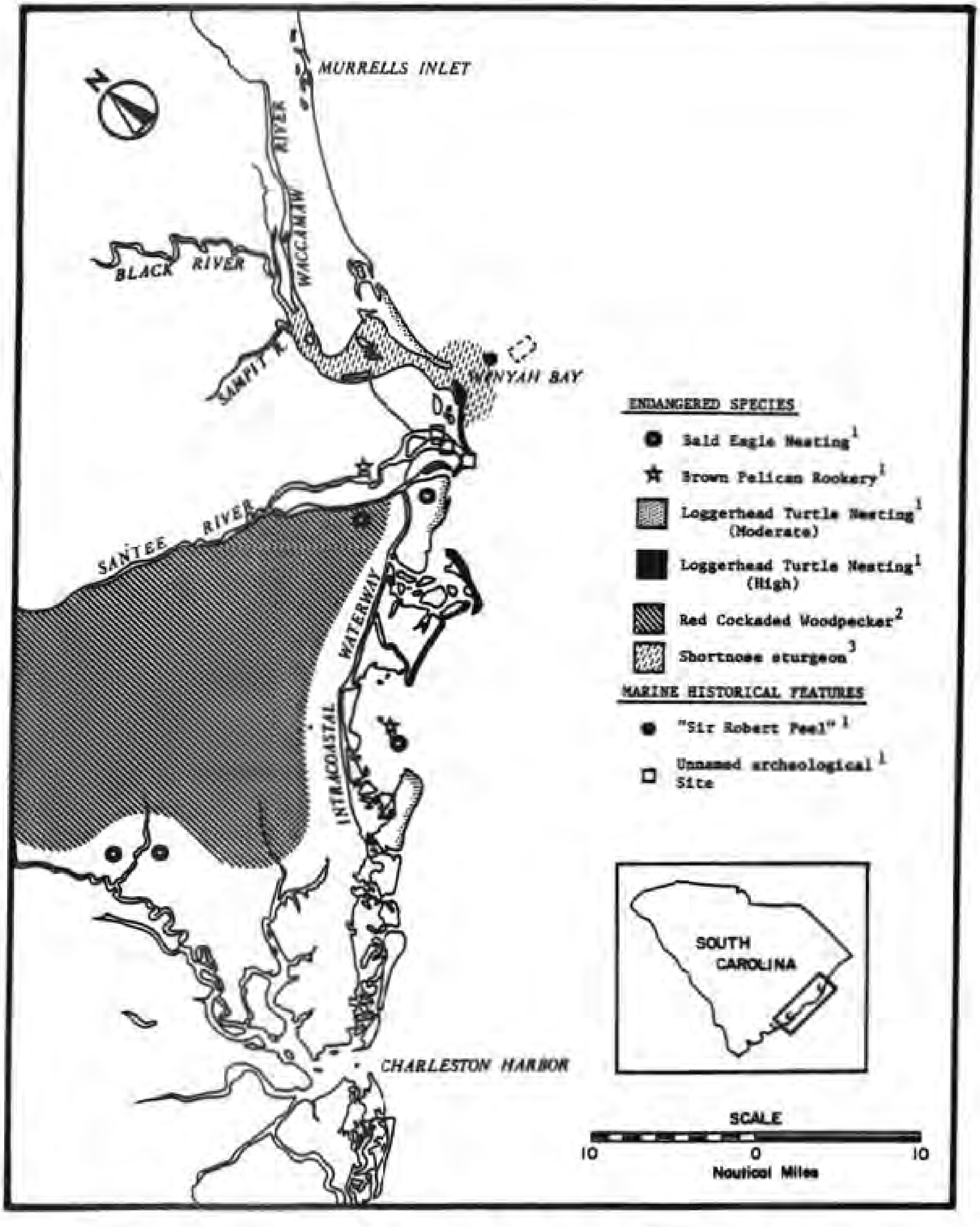


Figure 6. Location of endangered species and marine historical features: [1]Davis, et al., 1980; [2]BLM, 1981; [3]SCWMRD, unpublished.

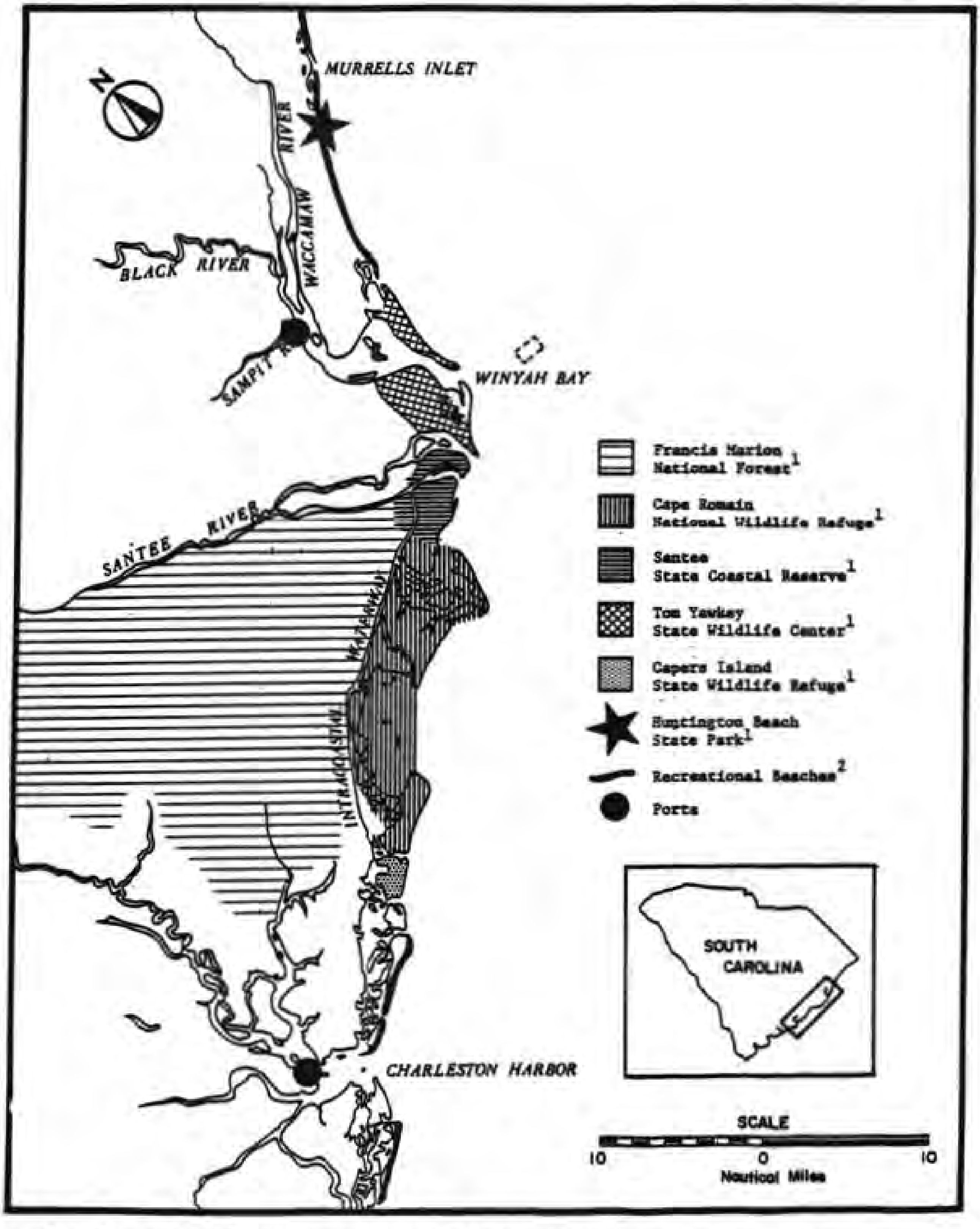


Figure 7. Location of preserves, wildlife centers, beaches and ports: [1]Davis, et al., 1980; [2]BLM, 1981.

since there are no piers or reefs nearby (Figure 5). Recreational fishing around the entrance channel jetties to Winyah Bay may be affected temporarily by increased water turbidity.

Natural and Artificial Reefs

The approximate locations of artificial reefs in the study region are identified in Figure 5. The "Georgetown Wreck" is the reef nearest the DMDS and is located approximately 5 miles to the northeast (Myatt, 1978). The only other reefs near the DMDS are the "Hector" and "City of Richmond" wrecks located approximately 9 miles to the south-southeast. It is unlikely that these reefs would be negatively influenced by disposal operations in the Georgetown DMDS, due to their distance from this site. Natural hard bottom reefs are not known to occur in the area around Winyah Bay; rather, most natural reefs are located further offshore (Henry and Giles, 1979; Miller and Richards, 1980; SCWMRD, 1982), or farther to the north (Parker et al., 1979). "East Bank", a shoal located approximately one mile to the southwest of the DMDS, may be a shell bank supporting sessile reef biota; however, no studies have been done on this bank.

Endangered Species

Habitat locations for endangered species in the study area are summarized in Figure 6. The two most important species that might be affected by offshore disposal operations are the shortnose sturgeon (Acipenser brevirostrum) and the loggerhead turtle (Caretta caretta). Shortnose sturgeon have been collected around the jetties in winter (Smith, T.I.J., pers. comm.), but this species spends most of its life in freshwater (Leland, 1968). The incidence of loggerhead turtle nesting is moderate on North Island and high on South Island (Davis et al., 1980). In South Carolina, adult females come ashore to nest from mid-May to mid-August, and many appear to use the waters around the DMDS during their movements (Hopkins and Murphy, 1981). The influence of disposal activities on turtle movements are not known, but effects would probably be limited to localized interruption of onshore migration rather than any direct impact on beach nesting areas.

Other Resources

The location of marine historical features, preserves, wildlife centers, recreational beaches and ports are shown in Figures 6 and 7. The only nearby historical feature, other than the shipwrecks mentioned previously, is the "Sir Robert Peel" wreck located just inshore of the DMDS. No historical features are known to be located within the DMDS. Although there are numerous preserves and wildlife centers along the coast, offshore disposal of sand sediments in the Georgetown DMDS is not expected to have any significant impact on the wildlife in these areas. Furthermore, disposal is not anticipated to adversely affect the nearest recreational beaches, which are located approximately 15 miles to the north of Winyah Bay. Finally, shipping to the port of Georgetown would not be impeded since the disposal area is located outside of the shipping channels.

Methods

LOCATION OF STUDY AREAS

The general location of stations sampled in this study is shown in Figure 8. Stations located in the Georgetown DMDS were within the boundaries defined by a rectangle having the following corner coordinates:

(1)	33°11'18"N 79°07'20"W	(2)	33°11'18"N 79°05'23"W
(3)	33°10'38"N 79°07'21"W	(4)	33°10'38"N 79°05'24"W

The control sites selected for study were also located within a rectangular area situated just north of the entrance channel to Georgetown Harbor. Water depths in this area were similar to the DMDS and the control area was approximately the same distance from shore. Coordinates of the corners of the control area were:

(1)	33°12'30"N 79°07'09"W	(2)	33°12'30"N 79°05'12"W
(3)	33°11'50"N 79°07'09"W	(4)	33°11'50"N 79°05'12"W

Within both the DMDS and the control sites, 15 points were located so that there were three rows of 5 equally spaced points (Figure 8). The four corner points in each area were located approximately 150 m inside the site boundaries. The east-west separation of points was approximately 680 m and the north-south separation of points was approximately 460 m. Five points from each of the above areas (DMDS, control) were randomly selected during winter (February 1983) and summer (July 1983) sampling periods using a stratified random selection technique; i.e., one point was randomly selected from each of the 5 columns of 3 points. This sampling design insured adequate sampling of each area for a complete representation of the bottom. The random sampling design also permitted appropriate statistical analyses. Stations selected for sampling during each season are listed in Table 1. All stations were located using Loran-C poisitiong with a Loran plotter system.

Based on the guidelines of Pequegnat et al. (1981) and on limited current data, two stations were located in the general direction of predominant nearshore currents, and a third

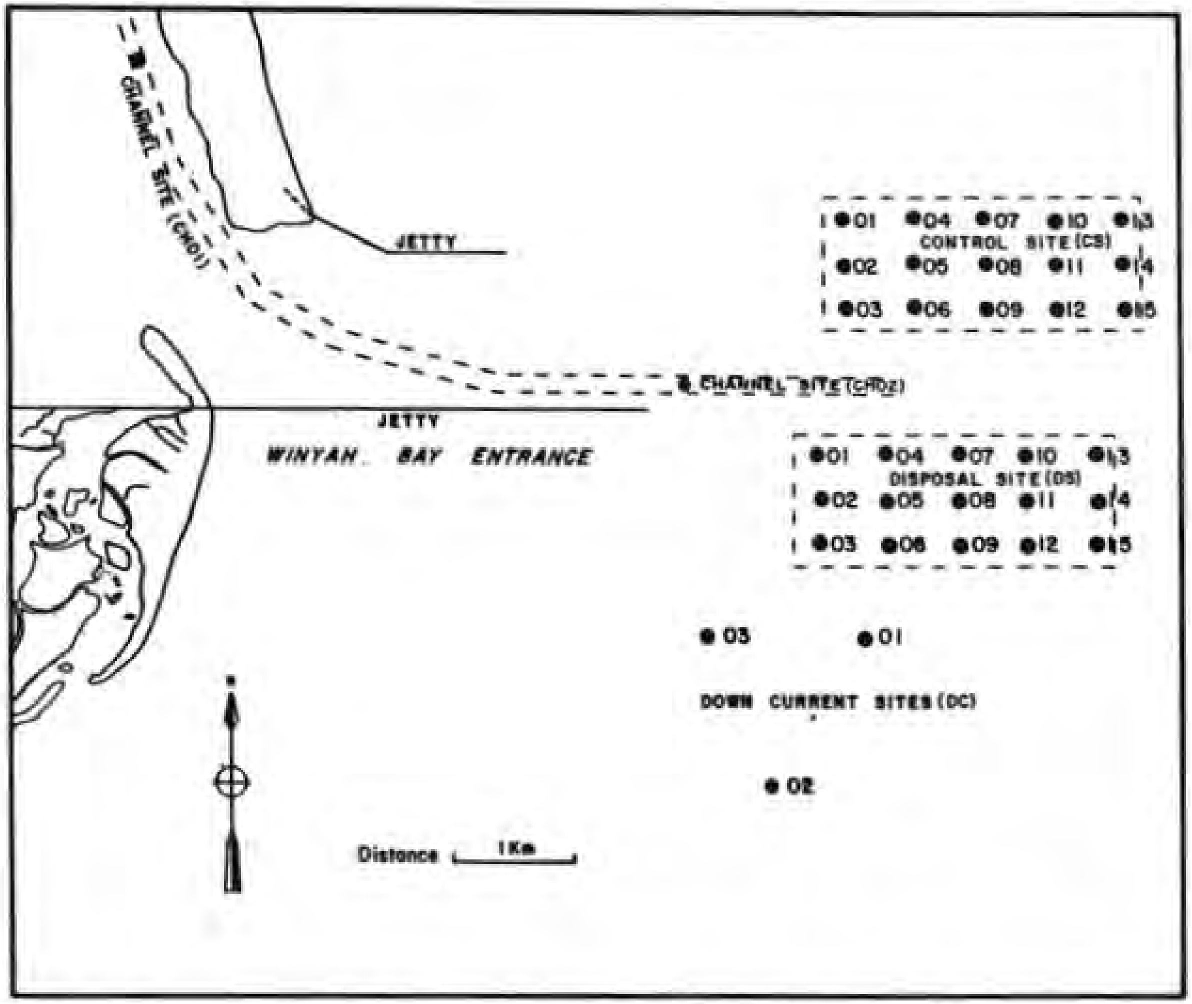


Figure 8. Map showing location of the 15 possible sampling locations in the control and DMDS sites, as well as the location of "down current" and channel sampling locations.

station was located between the DMDS and onshore resources. Coordinates for these stations, collectively referred to as "down current" stations (Figure 8), are listed in Table 1. Two additional stations were located in the entrance channel, one near the outer limit of the south jetty and one farther up the channel near the Georgetown lighthouse (Figure 8). These channel stations were only sampled during the summer season.

HYDROGRAPHIC ASSESSMENT

Temperature, salinity, dissolved oxygen and turbidity measurements were obtained at surface, midwater and bottom depth intervals using Van Dorn bottles. A standard thermometer was used for temperature measurements and Yellow Springs Instrument SCT-DO meters and probes (Model 33 SCT, Model 51 DO) were used to measure salinity and dissolved oxygen. The accuracy of these instruments was verified prior to sampling by separate measurements of a surface water sample taken at each site using a backup set of instruments. Turbidity samples were brought to the laboratory for measurement on a Hach Model 2100A turbidimeter. All water parameters were measured during winter and summer periods at nine stations: two in the DMDS area (most landward and most seaward stations), two in the control area (most landward and most seaward stations), the three "down current" stations, and the two channel stations (summer only).

During the summer sampling period, additional water samples were collected at four stations (CS09, DS08, DC02 and CH02) for analyses of oil and grease, lead, zinc, mercury, cadmium, arsenic, chromium, nickel, copper, PCBs (as Arochlor 1254), Heptachlor, DDT and metabolites, Endrin, Dieldrin, BHC, Mirex, Methoxychlor, Chlordane, Toxaphene and high-molecular-weight hydrocarbons. These samples were collected from bottom waters using a nonmetallic, acrylic, Van-Dorn type water bottle with silicon-coated end caps. The samples were collected, processed and analyzed in the laboratory using methods described by Pequegnat et al. (1981). In the case of trace metals, the alternative procedures described in Federal Registers (Vol. 44, No. 223, p. 69568; Vol. 44, No. 244, p. 75028; 1979) were used. Nutrients were measured using a Bausch and Lomb Model 70 spectrophotometer. Pesticides and hydrocarbons were measured using a Hewlett-Packard gas chromatograph, and oil and grease was measured by freon extraction. All metals were analyzed either on a Perkin-Elmer Model 306 or Model 460 atomic absorption spectrophotometer, with the Model 306 being used for all flame analyses plus the mercury flameless analysis, and the Model 460 being used for graphite furnace (flameless) analyses.

Current measurements were obtained at the 13 stations outside the channel during both seasons. An Endeco Model 110 current meter was used to obtain surface and bottom estimates of current speed and direction. All measurements were obtained while the research vessel was anchored on station. Surface measurements were obtained at approximately 3-m depth to insure that the instrument was at least 1 m below the vessel's keel. Bottom measurements were obtained approximately 1 m above the bottom. Intermediate current measurements were not taken due to the shallow water depths at the stations.

General meteorological and related observations were noted during every station visit. Observations included estimates of wind direction and speed, barometric pressure, cloud cover, precipitation, wave height and wave direction.

SEDIMENTOLOGICAL ASSESSMENT

Bottom sediments were collected at all 15 stations during the summer season using a Smith-McIntyre grab. This grab is designed to take an intact sample of offshore sandy sediments with minimal washout. Sediments were removed from the center of the first undisturbed grab sample collected at each site using methods described by Pequegnat et al. (1981).

Sediment subsamples for granulometric analyses were allowed to air dry and then disaggregated using a rubber-tipped pestle and split into two representative portions. One half of each sample was used for mineralogical analysis and the other for textural analysis. Those samples which contained significant quantities (more than a few percent) of material finer than 4 ϕ (0.0625 mm) were analyzed by both coarse sieving and pipette techniques.

A mineralogical analysis was performed on each of the samples to determine the percent weight of quartz and calcium carbonate (shells). Acid leaching using dilute (10%) HCl was utilized to determine the calcium carbonate content of the samples. Those samples which contained a high percentage of clay (making them very compact) were placed in distilled water and disaggregated using an ultrasonic dismembrator. After sample disaggregation was achieved, 200 ml of dilute HCl was added to dissolve the carbonate constituents. Upon complete leaching, the weight of the dried filtrate was determined and the percentage of acid-soluble calcium carbonate was calculated for each of the samples.

A grain size analysis of the bottom sediments was performed to determine the mean grain size, sorting, skewness and kurtosis for the samples. Grain size determinations were made using a Ro-tap mechanical shaker and 1/2 ϕ interval screens. The weight of the sediment retained on each screen (sieve fraction) was recorded. The weight percent and cumulative weight percent for each of the size classes were determined. These data were then plotted

Table 1. Geographic positions of sites sampled during the winter and summer, 1983.

SITE	STATION	SEASON	LATITUDE	LONGITUDE
DISPOSAL	DS03	winter, summer	33° 10.72'N	79° 7.23'W
	DS06	winter, summer	33° 10.72'N	79° 6.80'W
	DS08	summer	33° 10.97'N	79° 6.37'W
	DS09	winter	33° 10.72'N	79° 6.37'W
	DS10	summer	33° 11.22'N	79° 5.92'W
	DS11	winter	33° 10.97'N	79° 5.92'W
	DS13	winter, summer	33° 11.22'N	79° 5.48'W
CONTROL	CS02	winter, summer	33° 12.17'N	79° 7.05'W
	CS04	winter	33° 12.42'N	79° 6.62'W
	CS05	summer	33° 12.17'N	79° 6.62'W
	CS09	winter, summer	33° 11.92'N	79° 6.17'W
	CS10	winter	33° 12.42'N	79° 5.73'W
	CS11	summer	33° 12.17'N	79° 5.73'W
	CS13	winter, summer	33° 12.42'N	79° 5.30'W
DOWN CURRENT	DC01	winter, summer	33° 10.28'N	79° 6.92'W
	DC02	winter, summer	33° 9.53'N	79° 7.47'W
	DC03	winter, summer	39° 10.28'N	79° 7.88'W
CHANNEL	CH01	summer	33° 13.20'N	79° 11.35'W
	CH02	summer	33° 11.57'N	79° 8.0'W

to provide a cumulative frequency curve from which the statistical parameters were calculated according to Folk (1965).

A pipette analysis was performed on these samples which contained an appreciable amount of fine-grained material. These samples were dispersed by adding 100 ml of 1N sodium metaphosphate [$(NaPO_3)x \cdot Na_2O$)] as a dispersing agent and agitated using an ultrasonic dismembrator for 15 minutes. After complete deflocculation was achieved, the samples were wet-sieved through a #230-mesh stainless steel screen to separate the sand from the silt and clay. The silt and clay fraction was then transferred to a 1000-ml graduated cylinder and the sample was pipetted using the withdrawal times and depths as as outlined by Folk (1965). The percentages of sand, silt and clay were also recorded for these samples and plotted on a standard sediment-type triangular diagram.

Subsamples of sediment cores were also collected for analysis of the following parameters: Total organic carbon (TOC), chemical oxygen demand (COD), Kjeldahl nitrogen, nitrite nitrogen as NO_2, nitrate nitrogen as NO_3, oil and grease, lead, zinc, mercury, soluble phosphorus as PO_4, total phosphorus as PO_4, iron, cadmium, arsenic, chromium, nickel, copper, PCBs (as Arochlor 1254), Heptachlor, DDT and metabolites, Endrin, Dieldrin, BHC, Mirex, Methoxychlor, Chlordane, Toxaphene and high-molecular-weight hydrocarbons. All samples were preserved, processed and chemically analyzed using the procedures described by Pequegnat et al. (1981) and outlined for hydrographic analyses, except that metals were measured in two ways: after total extraction (bulk chemical analysis) and after partial extraction with 0.1N HCl. A second set of samples was collected from three stations (CS09, DS08, DC02) and preserved in the same manner for delivery to the Charleston District Corps of Engineers.

Sediment samples were not collected during the winter season. However, qualitative observations were made for each grab sample collected for benthos.

During summer, additional sedimentological studies included diver observations of the bottom. Unfortunately, very strong currents and extremely poor visibility drastically reduced the effectiveness of this effort and detailed results are not presented.

BENTHIC COMMUNITY ASSESSMENT

Macrofauna were sampled during both seasons at all randomly selected sites in the DMDS and control areas, as well as at the three "down current" stations. Prior to water chemistry or grab sampling during the winter, qualitative epifaunal samples were obtained at each of the 13 stations using a beam trawl similar to that described by Pequegnat et al. (1981). One tow was made in a north-south direction through each station, with all tow lengths standardized to 0.5 km based on Loran-C positioning. Similar beam trawls were made at the same 13 sites in summer, but only after sediment, grab and water chemistry sampling was completed in order to avoid disturbance of the bottom. Organisms obtained in each tow were preserved in 10% seawater-formaldehyde for later identification. Biomass estimates were also obtained for each sample.

Quantitative benthic samples of macrofauna were collected using a Smith-McIntyre grab while the research vessel was anchored on station. Five replicate samples were collected at each of the 13 stations (in addition to the separate sediment samples) both seasons. After measuring the volume of each grab sample, the collected material was washed through a 1-mm sieve. Organisms and sediment remaining on the sieve after washing were removed and preserved in 10% seawater-formaldehyde with rose bengal stain. Samples were then brought to the laboratory and organisms were sorted, identified to the lowest taxonomic level, and counted.

For qualitative collections by beam trawl, diversity was evaluated by comparing the number of species (*s*) among stations. The Kruskal-Wallis one-way analysis by ranks (Siegel, 1956) was used to determine whether median *s* differed significantly among the three areas sampled: disposal, control and down current. A significant difference in *s* between winter and summer was evaluated by the Mann-Whitney U-test (Sokal and Rohlf, 1982).

Qualitative data on the presence or absence of species collected with the beam trawl were analyzed by cluster analysis to determine patterns of similarity among stations and species. Only species which occurred in two or more trawl collections were included in this analysis.

Species and collections were classified using a flexible sorting strategy (Lance and Williams, 1967) with a cluster intensity coefficient (β) of -0.25. The Jaccard similarity coefficient (Clifford and Stephenson, 1975) was used with presence/absence data obtained from beam trawl collections.

Normal and inverse classifications were produced for combined seasonal data. The result of normal classification was a dendrogram in which collections were clustered based on their degree of similarity in terms of species presence. Inverse classification produced a dendrogram in which species were clustered based on their degree of similarity in terms of presence in collections (Williams and Lambert, 1961).

Subsequent to cluster analysis, species and station groups were chosen using a variable stopping rule (Boesch, 1977). Nodal analysis was then used to express the degree of species/site group coincidence in terms of ecological constancy and fidelity. Constancy expresses the frequency with which species of a particular group are found in a given collection group and fidelity measures the degree to which species are restricted to a particular collection group.

For trawl biomass estimates, a Model I two-way analysis of variance without replication was used to determine whether the mean log-transformed biomass of beam trawl collections differed significantly between seasons (winter, summer) and among areas (disposal, control, and "down current"). Due to non-normality and heterogeneous variances, a logarithmic $[\log_{10}(x+1)]$ transformation was used on each variate prior to calculation of means and analysis of variance.

Infaunal community structure based on grab collections was evaluated using several indices of species diversity and cluster analysis. Species diversity was calculated on the pooled samples collected during each station visit using Shannon's diversity index (H'), species richness (SR), and evenness (J') (Margalef, 1958; Pielou, 1975). Total number of species and faunal abundance were also evaluated. Normal and inverse cluster analyses were conducted on log-transformed abundance estimates from pooled (by station) grab samples using the Bray-Curtis similarity coefficient (Boesch, 1977). As with the trawl cluster analyses, a flexible sorting strategy with a standard cluster intensity coefficient (β) of −0.25 was used in both the normal and inverse analysis. Species which occurred in fewer than 7% of the 130 grab samples were deleted from the data set since rare species usually do not have easily defined distribution patterns and can confuse interpretation of cluster analysis. In all cases, species deleted because of rare occurrence were also rare in abundance. In order to accurately compare winter and summer data, bryozoans were also deleted prior to cluster analysis, since they were not enumerated during winter. Following normal and inverse analyses, a nodal analysis was performed using fixed station groups (DMDS, control, "down current", by season) and the inverse species groups to obtain estimates of fidelity and constancy as defined above.

BIOACCUMULATION ASSESSMENT

Specimens of the knobbed whelk, Busycon carica, were collected in the DMDS, control and "down current" areas for bioassay analysis. This mollusk was the only relatively sedentary organism which was present in all three sampling areas and was large enough to obtain sufficient biomass for analysis. The species is also commercially harvested in South Carolina. All B. carica specimens were collected from beam trawl samples taken in the three areas. After collection, specimens were preserved and analyzed according to the procedures outlined by Pequegnat, et al. (1981). All chemical contaminants, except oil and grease, which were analyzed in water samples were analyzed in the tissue samples.

Results and Discussion

HYDROGRAPHY

Water column chemistry in the study area can be influenced by runoff, nearshore and Gulf Stream current patterns, suspended sediments, eolian transport and other factors. As a result, the water chemistry may vary considerably on a temporal basis. Runoff from Winyah Bay and the Santee Rivers decreases salinities, increases turbidities and deposits fine sediments offshore. Normal runoff from these systems can be very high, with flows from the combined river systems being > 15,000 cfs (U.S. Geological Survey, 1979). In addition, a longshore drift to the southwest is usually present during summer months, while a northeasterly flow exists during winter months (Mathews and Pashuk, 1984). Therefore, depending on season and environmental conditions, waters from Winyah Bay may move either to the north or south along the coast as well as spread out towards deeper waters.

Oceanographic Parameters

Values recorded for the oceanographic parameters measured in this study generally agree with historic readings, although some of the salinities recorded during the winter cruise were particularly low. In that season, surface salinities were as low as 21.9 °/oo at station DC03 and < 30 °/oo at DC02, DS03 and DS13 (Table 2). These low salinities were the result of runoff from a massive rainstorm which preceded the winter sampling cruise. Summer salinities were generally higher than values observed during winter. Except for the station in Winyah Bay (CH01) which had salinities < 15 °/oo from surface to bottom, only one station (CS13) had surface water < 30 °/oo. During a two-year study in Winyah Bay, salinities at a station 2 miles upstream from the mouth averaged < 15 °/oo and ranged from < 2 °/oo to > 30 °/oo (Mathews and Shealy, 1982). Nearshore surface salinities off Winyah Bay are typically > 30 °/oo (Mathews and Pashuk, 1977, 1982, 1984).

Dissolved oxygen (DO) and water temperatures were also within normal ranges and DO was inversely related to temperature (Table 2). Both summer and winter DO concentrations were representative of the seasons sampled, with higher values (> 10 mg/l) being found in cold waters (< 9.0°C) and lower values (< 6 mg/l) found in warmer waters (> 26.5°C). Water temperatures were slightly cooler than usual for summer and winter, but not abnormally so (Mathews and Pashuk, 1984).

For all stations, turbidities were ≤ 8.0 FTU in surface samples and < 13.0 FTU in mid-water samples (Table 2). Highest values were normally encountered in bottom waters, where

Table 2. Oceanographic parameters of water collected from the 7 winter and 9 summer stations sampled in and near the Georgetown Harbor DMDS.

WINTER

Station	Station Depth	Depth	Temp. (C)	Salinity (°/oo)	D.O. (mg/l)	Turbidity (FTU)
DS03	8.0	Surface	8.7	27.2	10.4	5.5
		Middle	8.7	33.6	10.1	3.8
		Bottom	8.8	33.8	9.5	42.0
DS13	11.0	Surface	8.5	29.7	9.3	4.8
		Middle	8.6	34.1	9.1	3.8
		Bottom	8.7	34.1	9.2	5.2
CS02	9.5	Surface	9.2	30.0	9.2	4.6
		Middle	8.9	33.9	9.4	5.3
		Bottom	8.9	33.9	9.5	11.0
CS13	11.0	Surface	8.9	32.2	9.4	2.2
		Middle	9.0	34.0	9.2	2.8
		Bottom	8.9	34.0	9.3	6.1
DC01	8.75	Surface	9.4	33.1	9.0	2.0
		Middle	9.4	33.2	9.0	2.3
		Bottom	9.3	33.6	9.1	2.8
DC02	8.25	Surface	9.0	29.6	9.2	4.3
		Middle	9.0	30.7	9.0	6.5
		Bottom	9.0	33.6	9.9	13.0
DC03	6.5	Surface	8.5	21.9	9.8	8.0
		Middle	8.7	33.3	8.8	12.0
		Bottom	8.9	33.6	9.2	27.0

SUMMER

Station	Station Depth	Depth	Temp. (C)	Salinity (°/oo)	D.O. (mg/l)	Turbidity (FTU)
DS03	8.5	Surface	26.8	33.7	5.9	2.6
		Middle	26.5	34.4	5.5	3.8
		Bottom	26.7	34.3	5.8	24.0
DS13	12.0	Surface	27.0	34.5	5.8	6.7
		Middle	27.2	34.5	5.8	1.8
		Bottom	27.1	34.5	5.7	1.6
CS02	9.5	Surface	27.4	32.3	5.8	4.7
		Middle	26.7	34.2	5.5	5.8
		Bottom	26.8	34.3	5.6	8.8
CS13	10.5	Surface	27.8	27.9	5.9	5.6
		Middle	27.3	33.7	6.1	3.6
		Bottom	27.0	34.3	6.2	4.8
DC01	9.5	Surface	27.8	34.3	6.1	3.3
		Middle	27.0	34.3	6.0	3.7
		Bottom	27.1	34.4	5.8	3.4
DC02	7.3	Surface	27.3	32.6	6.2	2.9
		Middle	26.8	34.3	5.8	11.0
		Bottom	26.7	33.8	5.5	11.0
DC03	7.5	Surface	27.5	34.2	5.9	2.8
		Middle	27.0	34.2	6.0	3.5
		Bottom	27.4	34.3	6.0	8.8
CH01	7.5	Surface	29.0	12.1	7.2	7.7
		Middle	29.0	13.5	6.4	10.0
		Bottom	28.9	14.5	5.6	20.0
CH02	9.5	Surface	27.3	33.6	5.8	5.8
		Middle	27.1	33.7	5.5	13.0
		Bottom	26.9	34.1	5.4	28.0

greatest trubidity would be expected due to suspended sediments. In these bottom samples, turbidities in winter would have been influenced by the high runoff from Winyah Bay, which produced a maximum of 42.0 FTU at station DS03. The highest bottom turbidities in summer (up to 28.0 FTU) may have resulted from the activity of shrimp trawlers in the area during the summer sampling cruise.

Turbidities at the mouths of other South Carolina estuaries have greatly exceeded the maximum value recorded during this study. Mathews and Shealy (1982) and Mathews et al. (1981) reported maxima of 135 FTU at the mouth of Charleston Harbor, 91 FTU at the mouth of the South Santee River, and 84 FTU at the mouth of the North Santee River. Our winter and summer maxima were much lower (42.0 and 28.0 FTU, respectively) and, hence, well within the extremes noted at other nearby sites.

Currents

Measurements obtained at the 13 offshore stations indicate that water movement in the DMDS, control and "down current" areas is strongly influenced by tidal currents (Figures 9-10). Current velocities ranged from 0.1-0.9 knots during winter and 0.1-1.1 knots during summer sampling periods (Appendix 1). Surface and bottom currents generally flowed in a southerly or south-easterly direction during ebb tides. This suggests that water leaving Winyah Bay is diverted by nearshore currents which generally run in a southerly direction along the coast (Mathews and Pashuk, 1977). Current directions measured near slack-tide periods were more variable and often differed between surface and bottom waters. Generally, flood-tide currents were first detected near the bottom and ebb-tide currents were first observed in surface waters (Appendix 1). During flood tides, the general current direction was towards the north, or towards the Winyah Bay entrance channel. Thus, tidal currents appear to have a stronger influence on waters in the vicinity of the DMDS than nearshore currents. However, the limited current measurements collected during this study were only intended to supplement other hydrographic data and these measurements probably do not adequately define current regimes in the study area.

Chemistry and Pollutants

Trace metals were generally low in concentration, with many being below the detection limits, e.g. nickel, copper, lead and mercury (Appendix 2 and Table 3). The values reported in this study are generally much lower than values noted by Jones, Edmunds and Associates (JEA) (1979c.) in their study of the Georgetown Harbor channel, but were more similar to the Interstate Electronics Corp. (IEC) results (US EPA, 1982) obtained for the Charleston DMDS (Table 4). Specifically, our cadmium concentrations were higher than the IEC Charleston values (maxima of 7.1 µg/l and 0.493 µg/l, respectively), but much lower than the JEA Georgetown results (up to 150 µg/l). Nickel and lead concentrations measured in the present study were below the detection limit for each metal, whereas concentrations noted by JEA were as high as 760 µg/l for nickel and 1600 µg/l for lead. Zinc concentrations (minus estimates measured in the control blank sample) were lower than the concentrations noted by JEA, but arsenic concentrations were all higher than those measured by JEA, i.e., 32.4-92.8 µg/l versus < 10.0-30.0 µg/l (Table 4).

A study in Corpus Christi Bay by Holmes et al. (1974) found a seasonal variation in cadmium and zinc concentrations, but their overall results for estimates obtained in winter correlate well with this study. Summer values obtained by Holmes et al. (1974) were much higher due to stagnation within the bay, a condition clearly not present in our study area. Windom (1972) reported copper, lead, cadmium, zinc and mercury concentrations in the Savannah River before, during, and after dredging operations. He noted values of < 1 to 56 µg/l for copper, < 2.0 to 9.8 µg/l for lead, 0.05-0.49 µg/l for cadmium, 11-32 µg/l for zinc, and 0.15-0.21 µg/l for mercury. Our values were comparable, although we noted higher cadmium concentrations and lower lead concentrations (Table 4).

The various PCBs and pesticides listed in Table 4 were below the 50 ppb detection limits listed by Pequegnat et al. (1981) and, hence, they are assumed to be trace amounts. The oil and grease determination however, was positive but not particularly high. Our values ranged from 3.0-4.0 mg/l as compared to the JEA (1979c) range of 20-29 mg/l.

BOTTOM SEDIMENTS

Granulometric Analyses

Bottom sediments at stations sampled in the DMDS consisted of moderately to poorly sorted quartz sand having an average mean grain size of 0.71ϕ (Table 5, Figure 11). The silt and clay content of the five samples collected from this area was less than 1% (Table 6, Figure 12), suggesting that finer-grained sediments are winnowed out as a result of wave and current activity. Bottom sediments in this region are apparently not below the wave base, thus inhibiting deposition and allowing for removal of fine-grained sediments. The coarse sandy bottom present in the disposal area suggests that any fine-grained sediments previously disposed in the DMDS have been largely dispersed from the study area.

The concentration of calcium carbonate (shell material) varied from 4.66 - 14.97% in the disposal area (Table 7, Figure 13). Station DS03 had the highest concentration of calcium carbonate (14.97%) as a result of the abundance of both whole and fragmented shell material. Some of the shell material present may be from "East Bank" (a large

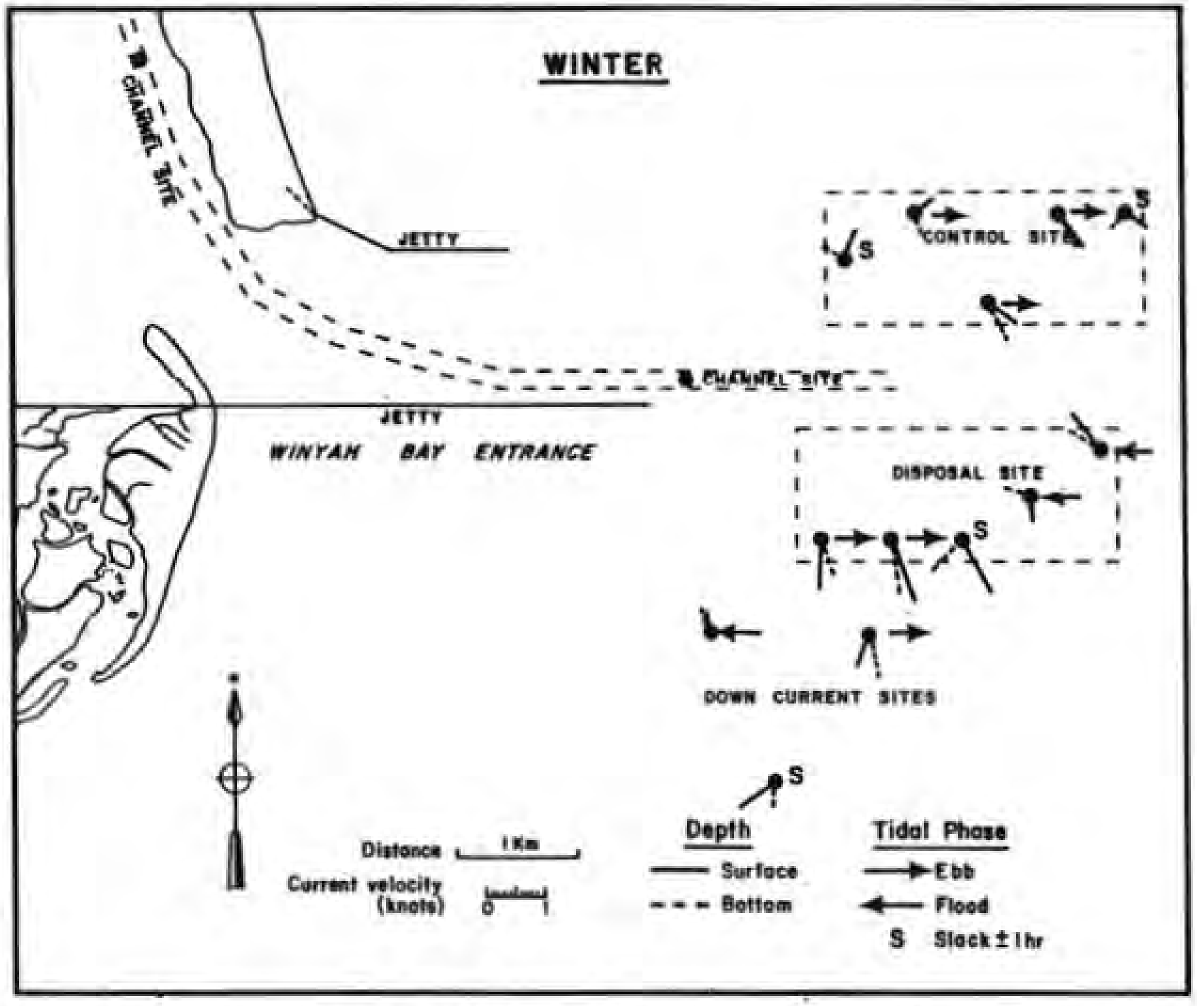


Figure 9. Current velocities and directions for the 13 stations sampled during the winter in and near the Georgetown Harbor DMDS.

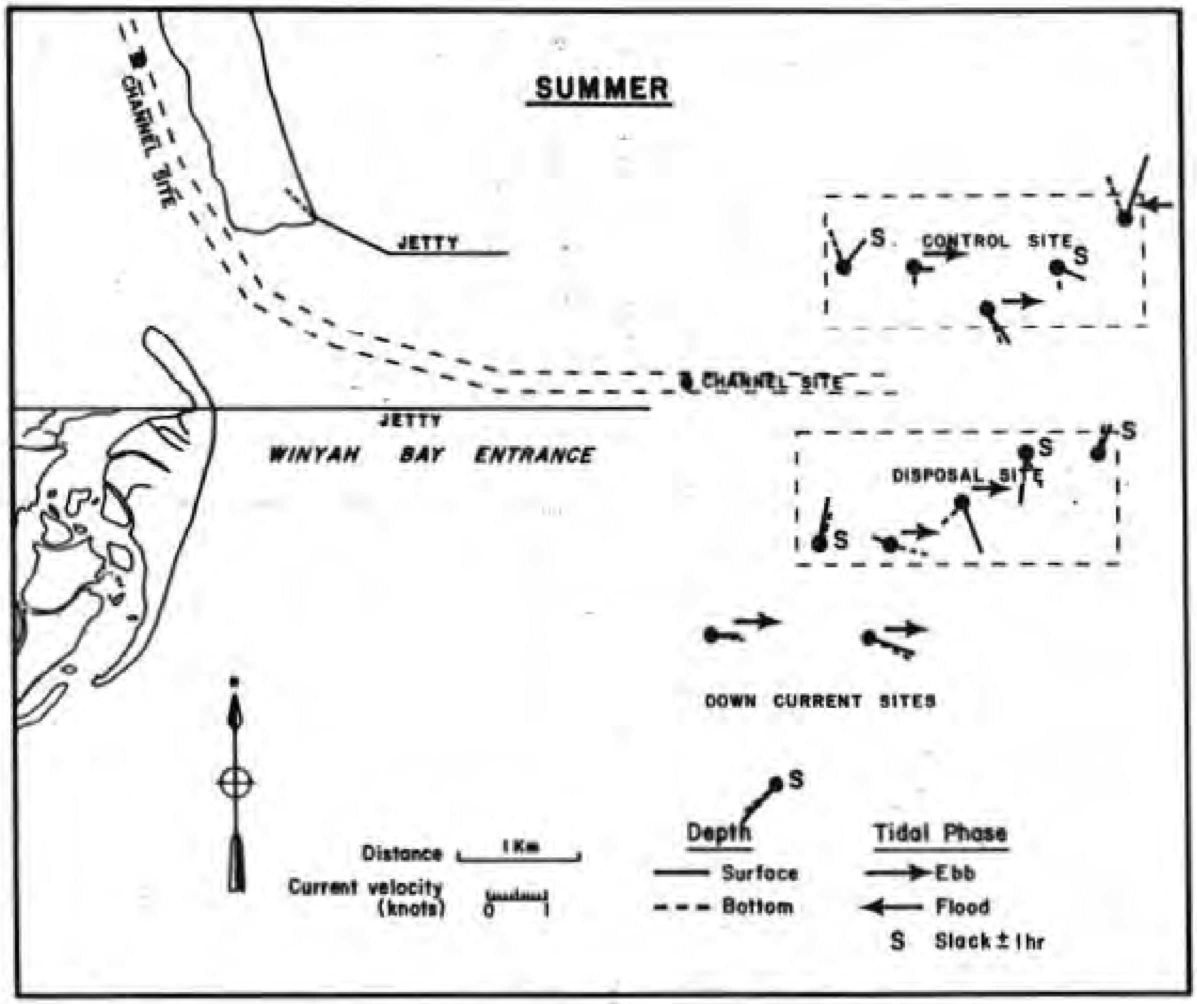


Figure 10. Current velocities and directions for the 13 stations sampled during the summer in and near the Georgetown Harbor DMDS.

Table 3. Maximum concentrations of various substances measured in sediment, water, and tissue samples collected from the vicinity of the Georgetown DMDS.

PARAMETER	SEDIMENT	WATER	TISSUE
Oil and grease	CH02 687 mg/kg	DS,DC 4.0 mg/l	ND
Nitrate as NO_3	CS13 533.33 mg/kg	NA	ND
Nitrite as NO_2	CH01 106.28 mg/kg	NA	ND
Total Kjeldahl Nitrogen	DC01 994 mg/kg	NA	ND
Soluble Phosphorus as PO_4	DS03 1.72 mg/kg	NA	ND
Total Phosphorus as PO_4	DC01 53.13 mg/kg	NA	ND
Total Organic Carbon	DC01 0.810% mg/g	NA	ND
Cadmium	ND	CS05 7.1 mg/l	ND
Arsenic	CS13 1.47 μg/g	CS05 92.8 mg/l	DS 2.34 mg/g
Chromium	ND	CS05 5.3 mg/l	ND
Nickel	ND	ND	ND
Copper	DC03 4.02 μg/g	ND	DS 9.65 mg/g
Iron	DC03 15,473 μg/g	ND	ND
Lead	ND	ND	ND
Mercury	DS08 0.61 μg/g	ND	ND
Zinc	CH02 41.04 μg/g	CH01 265 mg/l	DS 53.61 mg/g
Pesticides	ND	ND	ND
Total resolved Hydrocarbons	CS02 8.95 μg/g	CH01 416.63 mg/l	ND

ND - Not Detectable
NA - Not Analyzable

Table 4. Comparisons of hydrographic chemical analyses for Georgetown and Charleston Harbor areas.

	GEORGETOWN DMDS					
	CHANNEL CH01	CONTROL CS05	DISPOSAL DS08	DOWN CURRENT DC02	IEC * CHARLESTON ODMDS	JEA ** GEORGETOWN HARBOR CHANNEL
PCBs Aroclor 1254 μg/l	ND	ND	ND	ND	ND	< 1.0
BHC μg/l	ND	ND	ND	ND	ND	< 0.5
lindane μg/l	ND	ND	ND	ND	ND	NA
heptachlor μg/l	ND	ND	ND	ND	ND	< 0.5
DDE μg/l	ND	ND	ND	ND	ND	< 0.5
DDD μg/l	ND	ND	ND	ND	ND	< 0.2
DDT μg/l	ND	ND	ND	ND	ND	< 0.2
chlordane μg/l	ND	ND	ND	ND	ND	< 0.5
dieldrin μg/l	ND	ND	ND	ND	ND	< 0.1
endrin μg/l	ND	ND	ND	ND	ND	< 0.2
mirex μg/l	ND	ND	ND	ND	ND	< 0.3
methoxychlor μg/l	ND	ND	ND	ND	ND	< 1.0
toxaphene μg/l	ND	ND	ND	ND	ND	< 5.0
Oil and Grease μg/l	3.0	3.0	4.0	4.0	NA	20 - 29
Cadmium μg/l	0.8	7.1	1.6	3.4	0.040 - 0.493	110 - 150
Arsenic μg/l	78.6	92.8	41.4	32.4	NA	< 10.0 - 30.0
Chromium μg/l	1.4	5.3	4.7	2.1	NA	< 300
Nickel μg/l	< 5.0	< 5.0	< 5.0	< 5.0	NA	600 - 760
Copper μg/l	< 50	< 50	< 50	< 50	NA	< 100
Lead μg/l	< 1.0	< 1.0	< 1.0	< 1.0	0.032 - 3.20	1100 - 1600
Mercury μg/l	< 0.2	< 0.2	< 0.2	< 0.2	< 0.03 - 0.076	< 0.2
Zinc μg/l	265	150	172	172	NA	140 - 240

* IEC Interstate Electronics Corp. (IEC), US EPA (1982)
** JEA Jones Edmunds and Associates. (1979c)
NA - Not Analyzed
ND - Not Detected; Detection Limit is 50 ppb.

Table 5. Statistical analysis of the grain size distribution for sediments from the Georgetown DMDS and vicinity. Data presented in ∅ units.

STATIONS	MEAN	MEDIAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
DS03	0.16	0.90	1.41	-0.56	0.83
DS06	0.91	1.10	0.83	-0.32	1.24
DS08	0.86	1.15	1.05	-0.45	0.94
DS10	0.80	1.10	0.78	-0.50	0.75
DS13	0.84	1.08	0.79	-0.39	1.04
CS02	0.83	1.15	0.83	-0.52	1.20
CS05	0.78	1.15	0.85	-0.58	1.34
CS09	0.60	0.70	1.00	-0.15	1.06
CS11	1.13	0.45	2.52	+0.48	2.12
CS13	0.83	1.08	0.95	-0.36	0.85
DC01	1.89	2.00	0.65	-0.39	1.27
DC02	1.03	1.20	0.85	-0.42	1.81
DC03	4.59	4.60	2.56	+0.05	0.83
CH01	1.58	1.50	0.83	-0.05	1.09
CH02	3.73	3.10	1.88	+0.53	1.02

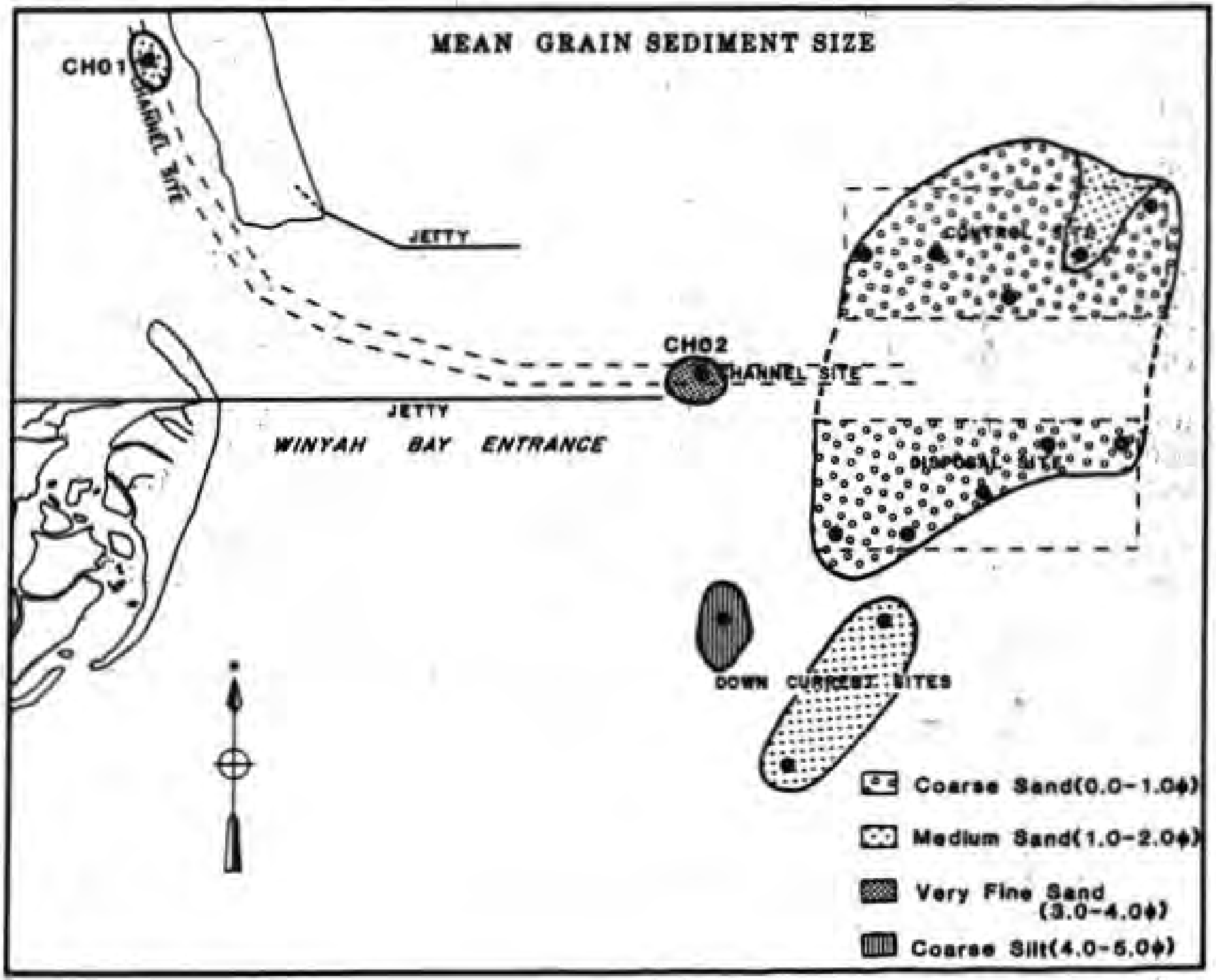


Figure 11. Distribution of mean grain size of sediments collected from the Georgetown DMDS and vicinity.

Table 6. Percentages of sand, silt and clay in sediments from the Georgetown DMDS and vicinity. Estimates represent percent by weight.

<table>
<tr><th>STATIONS</th><th>SAND</th><th>SILT</th><th>-</th><th>CLAY</th></tr>
<tr><td>DS03</td><td>99.74</td><td colspan="3">0.26</td></tr>
<tr><td>DS06</td><td>99.96</td><td colspan="3">0.04</td></tr>
<tr><td>DS08</td><td>99.33</td><td colspan="3">0.67</td></tr>
<tr><td>DS10</td><td>100</td><td colspan="3">trace</td></tr>
<tr><td>DS13</td><td>100</td><td colspan="3">trace</td></tr>
<tr><td>CS02</td><td>99.40</td><td colspan="3">0.60</td></tr>
<tr><td>CS05</td><td>99.98</td><td colspan="3">0.02</td></tr>
<tr><td>CS09</td><td>99.46</td><td colspan="3">0.54</td></tr>
<tr><td>CS11</td><td>83.66</td><td>6.42</td><td></td><td>9.92</td></tr>
<tr><td>CS13</td><td>99.85</td><td colspan="3">0.15</td></tr>
<tr><td>DC01</td><td>99.11</td><td colspan="3">0.89</td></tr>
<tr><td>DC02</td><td>99.88</td><td colspan="3">0.12</td></tr>
<tr><td>DC03</td><td>37.89</td><td>27.39</td><td></td><td>34.72</td></tr>
<tr><td>CH01</td><td>99.94</td><td colspan="3">0.06</td></tr>
<tr><td>CH02</td><td>54.72</td><td>20.09</td><td></td><td>25.19</td></tr>
</table>

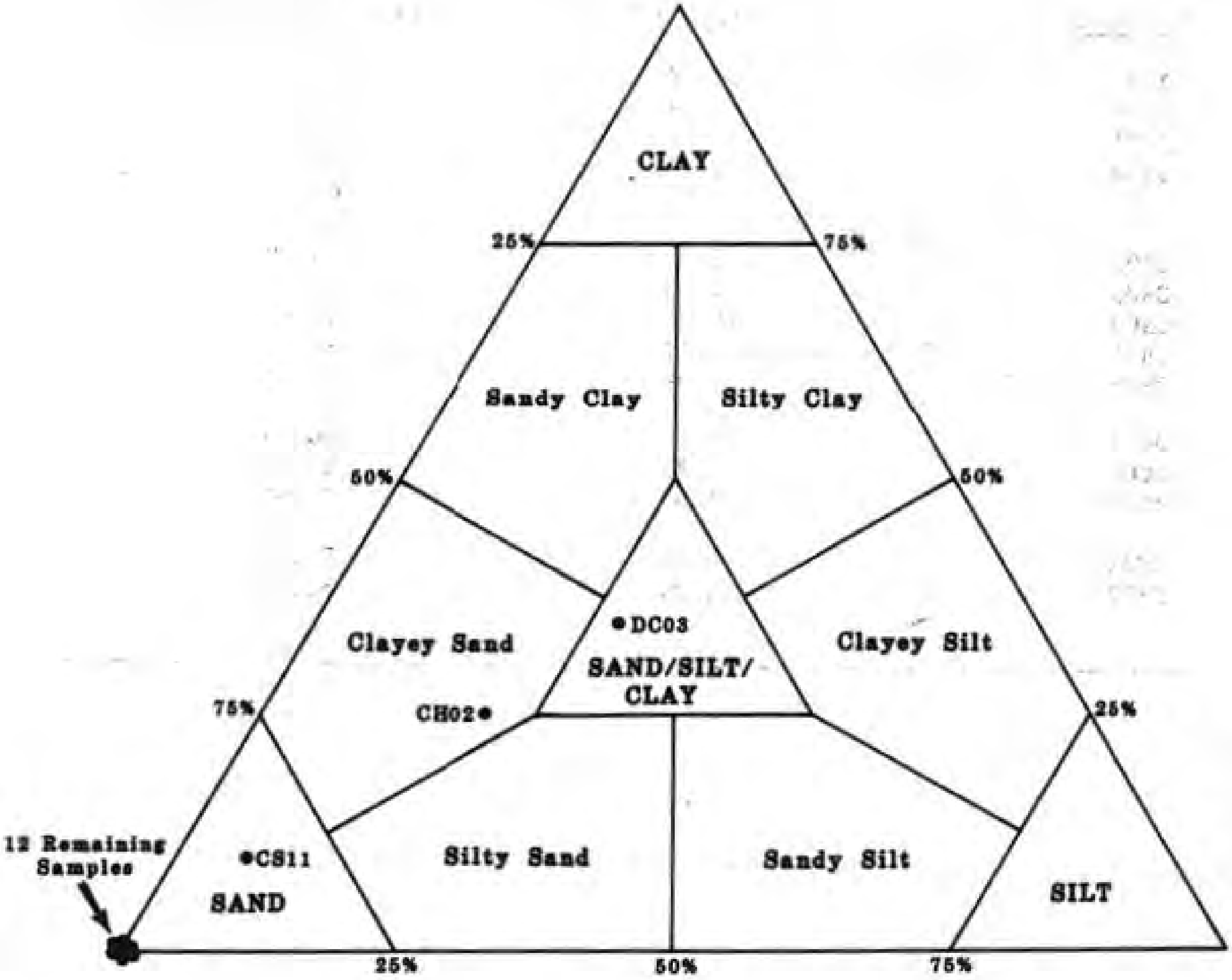


Figure 12. Shepard's classification of sediment types at stations in the Georgetown DMDS and vicinity.

Table 7. Calcium carbonate content of sediments from the Georgetown DMDS and vicinity. Estimates represent percent by weight.

STATIONS	$CaCO_3$ (Shell)	QUARTZ (Non-carbonates)
DS03	14.97	85.03
DS06	6.18	93.82
DS08	8.39	91.61
DS10	5.26	94.74
DS13	4.66	95.34
CS02	6.00	94.00
CS05	7.33	92.67
CS09	10.88	89.12
CS11	10.65	89.35
CS13	10.09	89.91
DC01	9.65	90.35
DC02	6.33	93.67
DC03	27.69	72.31
CH01	3.46	96.54
CH02	16.38	83.62

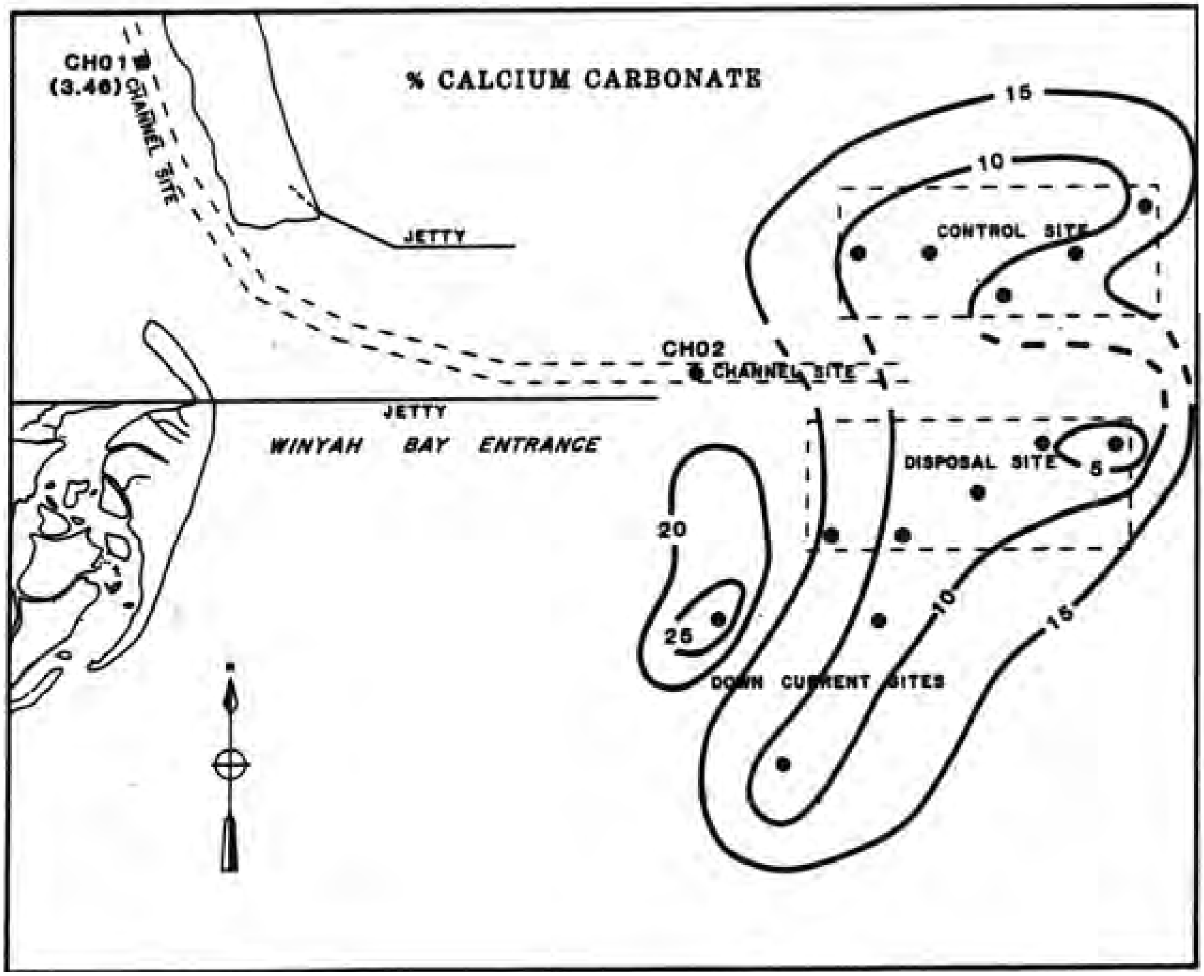


Figure 13. Distribution of percent calcium carbonate content of sediments collected from the Georgetown DMDS and vicinity.

shell bank) located to the west of the DMDS.

Like those at DMDS sites, bottom sediments at control sites consisted primarily of moderately to poorly sorted clean coarse sand having an average mean grain size of 0.83ϕ (Table 5, Figure 11). All of the control site stations, with the exception of station CS11, contained less than 1% by weight of silt and clay (Table 6, Figure 12). Sediments at CS11 consisted of medium sand containing 6.42% silt and 9.92% clay. The average mean grain size of these bottom samples was not significantly different from that of the disposal area ($P > 0.05$, ANOVA). Values obtained for the concentration of calcium carbonate (shell material) are, however, slightly higher in the control area (Table 7, Figure 13).

Bottom sediments collected at the "down current" sites differed from sediments found in the DMDS and control areas. Medium quartz sand was present at DC01 and DC02 (Figure 11), and DC03 consisted mostly of a calcareous coarse silt (Tables 5-7, Figures 11-13). The accumulation of this fine-grained shell hash (27.19% $CaCO_3$) may result from wave abrasion of shell material present on "East Bank". All three samples collected from the "down current" sites were consistently finer-grained than those samples examined from either the control or disposal sites (Table 5), although differences were not statistically significant ($P > 0.05$, ANOVA). The decrease in grain size suggests a southerly current dispersal pattern for the sediments in the area.

The two samples collected from the entrance channel leading into Georgetown Harbor differed from sediments collected at most of the offshore stations. Station CH02, located near the seaward extension of the jetties, consisted of poorly sorted clayey sand (Tables 5-7). The high concentration of silt and clay (45.28%) suggests that the channel acts as a settling basin for the deposition of silt and clay. This sample also contained a high concentration (16.38%) of calcium carbonate (Table 7). Station CH01, located further up the bay, consisted of moderately sorted, clean medium sand. Both of these samples suggest that the sediment currently being deposited within the channel is finer-grained than the sediment found within the control or disposal sites located offshore.

Bottom sediments observed by divers showed evidence of wave disturbance at some stations but not at others. Divers also observed wave influence of sediments at stations in the Charleston DMDS which were even deeper than those sampled in the Georgetown DMDS (SCWMRD, 1979). Thus, it is probable that wave disturbance is an important factor influencing bottom sediments in the Georgetown DMDS.

Chemistry and Pollutants

Although contaminant concentrations were quite low for most of the water samples collected in this study, they were much higher in the sediments. The higher concentrations measured, however, are not abnormal. The usual sources of contamination in sediments are the same as those for water pollution, i.e. runoff from urban areas, eolian transport, various industrial sources and occasional spills. Depending upon current regimes, flushing rates, and mixing processes, contaminant loads in the sediments can be insignificant or relatively high. As noted previously, dispersal of suspended sediments near Winyah Bay should be rather widespread, thus precluding the buildup of contaminants in a small geographic area.

Maximum trace metal concentrations measured in this study are presented in Table 3 and Appendix 3. The extreme concentrations are listed in Table 8 for each site and are compared with previous studies in the Charleston DMDS (US EPA, 1982, SCWMRD, 1979). Utilizing the total digestion procedures, our concentration ranges exceeded values noted in the Charleston DMDS for iron, nickel and zinc (Table 8). Highest concentrations of these metals occurred at the channel station CH02. The high iron concentrations may be due to long-term industrial discharges. All trace metal concentrations measured in our study were within (or lower than) the extremes noted by Chen et al. (1976).

Windom (1973) found mercury in marsh sediments along the Savannah River up to 4 µg/g, considerably higher than our maximum of 0.61 µg/g. In addition, Holmes et al. (1974) reported zinc concentrations in Corpus Christi Bay sediments from 6-235 µg/g and cadmium from 0.1-1.9 µg/g. In each case, the maximum concentrations noted far exceeded our maxima, i.e. 235 µg/g versus 41.04 µg/g and 1.9 µg/g versus < 0.1 µg/g. In a 1971 study at Winyah Bay, Johnson (1972) observed sediment concentrations of 48-76 µg/g copper, 92 µg/g zinc, 3,800-4,800 µg/g iron, 8-12 µg/g arsenic, 4.0-16 µg/g lead, 0.063-0.088 µg/g mercury at a station 9-12 miles up river from the mouth. No detectable cadmium or chromium concentrations were noted in that study. Concentrations detected in our study using total digestion were higher for mercury, iron, and chromium; lower for lead, arsenic, copper, and zinc; and similar for cadmium (Appendix 3).

Utilizing data obtained by partial extraction with 0.1 N HCl, we found all metals except lead to be lower in concentration as compared to total digestion (Appendix 3). Partial extraction tends to remove the readily-leached metals from the sediments, which might be available for bioconcentration. Values we observed, based on partial extraction, were generally similar to the concentrations noted in <u>Busycon</u> <u>carica</u> tissue (Appendices 3 and 12). Copper and zinc concentrations, however, were higher in the <u>B</u>. <u>carica</u> tissue than in the sediments, and the concentration of lead in the sediments at CH02 was higher than that noted in <u>B</u>. <u>carica</u>. Bothner et al. (1980) found zinc concentrations virtually identical to ours in sediments from an area southeast of Winyah Bay at mid- to outer-shelf depths.

Table 8. Comparisons of geochemical analyses of sediments for Georgetown and Charleston Harbor areas.

	GEORGETOWN DMDS				IEC * CHARLESTON ODMDS	SCWMRD ** CHARLESTON HARBOR ODA
	CHANNEL	CONTROL	DISPOSAL	DOWN CURRENT		
PCBs Aroclor 1254 μg/g	ND	ND	ND	ND	0.000492	NA
DDE μg/g	ND	ND	ND	ND	0.000027 - 0.00005	NA
TOC %	0.086 - 0.549	0.047 - 0.529	0.057 - 0.120	0.060 - 0.810	0.05 - 12.5	< 1.0
Oil and grease mg/kg	< 6 - 687	8 - 206	< 6 - 105	< 10 - 507	9 - 63	< 10 - 22
Nitrate as NO_3 mg/kg	57.97 - 278.57	15.44 - 533.33	17.55 - 32.66	50.77 - 392.0	NA	0.2 - 1.9
Nitrite as NO_2 mg/kg	10.0 - 106.28	0.34 - 8.04	0.21 - 81.31	3.96 - 27.45	NA	0.1 - 0.2
Total Kjeldahl Nitrogen mg/kg	40 - 546	29 - 266	20 - 807	31 - 994	NA	< 100 - < 1000
Soluble Phosphorus as PO_4 mg/kg	1.20 - 1.63	0.231 - 1.01	0.849 - 1.72	0.304 - 1.20	NA	< 0.1 - 2.2
Total Phosphorus as PO_4 mg/kg	8.43 - 34.72	8.11 - 15.44	5.82 - 11.26	5.92 - 53.13	NA	700 - 13800
Cadmium μg/g	< 0.1	< 0.1	< 0.1	<0.1	NC	< 0.1 - 0.4
Arsenic μg/g	1.38 - 1.44	0.41 - 1.47	.36 - 1.36	1.07 - 1.38	NA	1.1 - 10.0
Chromium μg/g	1.25 - 14.9	<0.1 - 8.50	1.16 - 2.46	1.22 - 9.05	NA	7.0 - 38.0
Nickel μg/g	<0.5 - 9.95	< 0.5	<0.5 - 5.89	< 0.5	NA	< .5 - 7.3
Copper μg/g	<0.1 - 2.49	<0.1	<0.1 - 1.02	<0.1 - 4.02	NA	8.0 - 27.0
Iron μg/g	5,075 - 15,473	2,175 - 8,308	2,180 - 4,227	3,608 - 11,558	NA	1,800-6,800
Lead μg/g	< 0.5	< 0.5	< 0.5	< 0.5	NC	< 0.5 - 2.5
Mercury μg/g	0.27 - 0.51	0.11 - 0.38	0.08 - 0.61	0.21 - 0.55	0.001 - 0.005	.06 - 1.13
Zinc μg/g	9.60 - 41.04	7.64 - 22.89	5.38 - 11.14	7.83 - 23.77	NA	6.0 - 28.0

* Interstate Electronics Corp. (US EPA, 1982)
** South Carolina Wildlife and Marine Resources Dept. (1979)
NA - Not Analyzed
ND - Not Detected; Detection Limit is 50 ppb.
NC - Not Comparable; differing analyses.

Their partial leaching technique used as 5.0 N HNO_3 and, hence, resulted in higher concentrations for chromium and copper. Their findings indicated no accumulations of anthropogenic metals in sediments of the continental shelf off South Carolina.

No PCBs or pesticides were detected ($\geq$ 50 g/kg) in the sediments at any of the stations (Table 8, Appendix 3). Concentrations of DDD, DDE and dieldrin have been reported as high as 4.2 μg/kg, 3.4 μg/kg, and 9.1 μg/kg, respectively in Winyah Bay sediments (Johnson, 1970). Our results at the mouth and offshore may have been somewhat higher than these, since our detection limit was 50 μg/kg. Chen et al. (1976) reported extremes for both PCBs and pesticides of 0-10 μg/kg. Without finer resolution, we can only conclude that our samples may have been within these limits.

Total organic carbon (TOC) measurements yielded values from 0.47 mg/g at CS05 to 8.10 mg/g at DC01. These extremes coincide with values reported for the Charleston DMDS (Table 8). Oil and grease determinations ranged from a low of < 6 mg/kg at CH01, DS03, and DS06, to a high of 687 mg/kg at CH02. Our maximum at each site greatly exceeded the oil and grease concentrations reported for the Charleston DMDS (Table 8). Our TOC and oil and grease values, however, were relatively low compared to concentrations reported by Chen et al. (1976).

Sediment nutrient concentrations varied considerably between sampling sites (Appendix 3). The maximum nitrate concentrations (531.33 mg/kg) occurred at CS13, while the minimum (15.44 mg/kg) was recorded at CS05. Sediments in the disposal site generally had much lower concentrations of nitrate than the other sites (17.55-32.66 mg/kg). All sampling sites surveyed in this study had much higher nitrate levels than stations sampled in the Charleston DMDS (Table 8). Nitrite was similarly variable with respect to location and much higher than reported in the Charleston DMDS (Table 8).

Total Kjeldahl nitrogen ranged from 20-994 mg/kg with great variability between the sampling sites (Table 8). The overall magnitude of concentrations, however, agreed with values reported for the Charleston DMDS (< 100 - < 1000 mg/kg).

BENTHIC COMMUNITIES

Beam Trawl Collections

Beam trawl collections taken during winter and summer yielded 3 algal species, 126 invertebrate taxa, and 28 fish species (Appendix 4). Of the invertebrates collected, more species of arthropods (44 species) were collected than any other taxonomic group. Groups of lesser importance included cnidarians (21 species), bryozoans (21 species) and mollusks (15 species) which, together with the arthropods, accounted for 81% of the total invertebrate taxa in beam trawl collections. These groups also accounted for the largest number of species in dredge collections from Winyah Bay (Hinde et al., 1981) and the ocean disposal area near Charleston Harbor (Van Dolah et al., 1983), although the order of their importance differed among the studies.

Decapod crustaceans dominated the three areas sampled during winter and summer in terms of percent contribution of species (Figure 14). Fish were also important at most sites, except for control stations sampled in winter, where bryozoans ranked second to decapod crustaceans in number of species. For all stations combined, bryozoans were more diverse in winter than summer, whereas the number of cnidarian and fish species increased in summer.

Species which occurred in more than half of the 26 collections taken from the three areas sampled were the portunid crabs *Ovalipes stephensoni* and *Portunus gibbesii*; the hydroid *Halecium* sp.; the penaeid shrimp *Trachypenaeus constrictus*; the bryozoan *Membranipora tenuis*; and the sciaenid fish *Leiostomus xanthurus*. Only one of these species, *M. tenuis*, was also frequently encountered by Hinde et al. (1981) and Van Dolah et al. (1983) in faunal surveys of Winyah Bay and the Charleston DMDS, respectively. Seasonal comparisons of the most frequently encountered species in beam trawl collections indicated that only *O. stephensoni*, *P. gibbesii*, *T. constrictus*, and *M. tenuis* were widespread in both winter and summer (Table 9). In addition, more taxa were frequently encountered during summer collections than during winter, suggesting a seasonal change in the occurrence of certain taxa within the three areas sampled.

Seasonality also apparently had an effect on the number of species (*s*) occurring in the study areas. The median number of species collected in summer (120 total taxa) was significantly greater than in winter (88 total taxa) ($P < 0.05$). This pattern was consistent for each of the three areas sampled and, with only two exceptions (DS03, DC03) was also consistent for sites sampled during both winter and summer (Figure 15). The high number of species observed at DC03 in winter was probably related to the presence of a large quantity of submerged wood, which provided suitable substrate for epifaunal colonization. Submerged substrates such as shell and wood occurred in varying quantities at several stations and no doubt contributed to much of the variation in number of species among stations (Figure 15).

No consistent trends and no statistically significant differences in median *s* were found among the three sampling areas ($P > 0.05$). However, a comparison of total *s* among these areas indicated that stations in the control site yielded the most (115) species, whereas "down current" and disposal stations yielded 86 and 65 species, respectively. This is noteworthy in view of the fact that equal

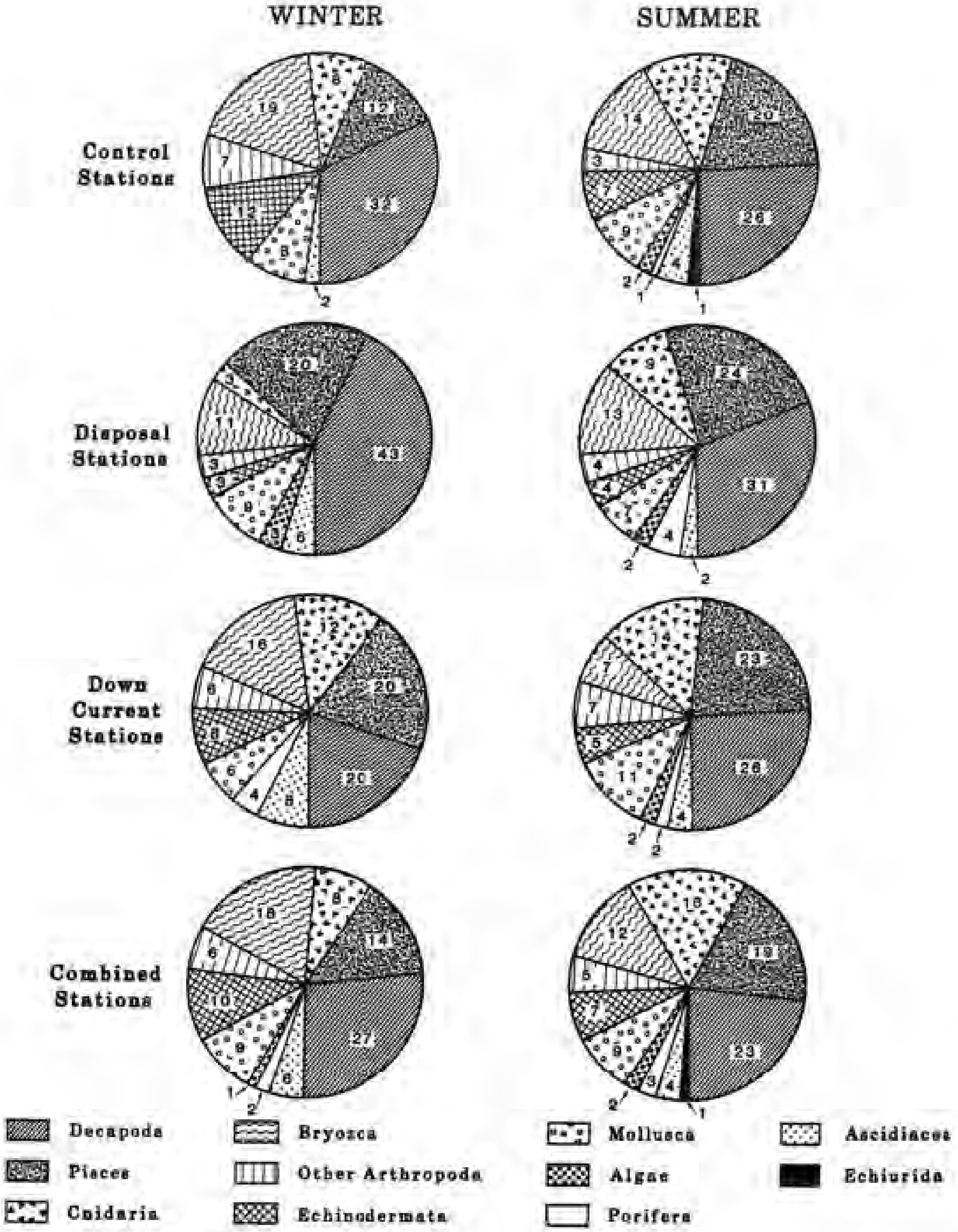


Figure 14. Percentage contribution of major taxa to the species composition of beam trawl collections.

Table 9. Species ranked according to their frequency of occurrence (F) in ≥ 50% of beam trawl collections. (Cn = Cnidaria, Ch = Chordata, Ar = Arthropoda, Bry = Bryozoa, Ech = Echinodermata, Mo = Mollusca, Po = Porifera, Al = Algae).

CONTROL STATIONS	F	DISPOSAL STATIONS	F	DOWN-CURRENT STATIONS	F	COMBINED STATIONS	F
				WINTER			
Halecium sp. (Cn)	5	*Ovalipes stephensoni* (Ar)	5	*Brevoortia tyrannus* (Ch)	3	*Ovalipes stephensoni* (Ar)	12
Brevoortia tyrannus (Ch)	4	*Portunus gibbesii* (Ar)	4	*Anchoa mitchilli* (Ch)	3	*Portunus gibbesii* (Ar)	11
Ovalipes stephensoni (Ar)	4	*Brevoortia tyrannus* (Ch)	3	*Ovalipes stephensoni* (Ar)	3	*Halecium* sp. (Cn)	11
Portunus gibbesii (Ar)	4	*Trachypenaeus constrictus* (Ar)	3	*Ovalipes ocellatus* (Ar)	3	*Brevoortia tyrannus* (Ch)	10
Membranipora tenuis (Bry)	4	*Halecium* sp. (Cn)	3	*Portunus gibbesii* (Ar)	3	*Trachypenaeus constrictus* (Ar)	8
Parasmittina nitida (Bry)	4			*Halecium* sp. (Cn)	3	*Libinia emarginata* (Ar)	7
Trachypenaeus constrictus (Ar)	3			*Urophycis regius* (Ch)	2	*Membranipora tenuis* (Bry)	7
Pagurus pollicaris (Ar)	3			*Etropus crossotus* (Ch)	2		
Libinia emarginata (Ar)	3			*Scophthalmus aquosus* (Ch)	2		
Asterias forbesii (Ech)	3			*Symphurus plagiusa* (Ch)	2		
				Trachypenaeus constrictus (Ar)	2		
				Libinia emarginata (Ar)	2		
				Membranipora tenuis (Bry)	2		
				SUMMER			
Pagurus pollicaris (Ar)	5	*Ovalipes stephensoni* (Ar)	5	*Micropogonias undulatus* (Ch)	3	*Ovalipes stephensoni* (Ar)	13
Ovalipes stephensoni (Ar)	5	*Prionotus carolinus* (Ch)	4	*Prionotus carolinus* (Ch)	3	*Portunus gibbesii* (Ar)	11
Calliactis tricolor (Cn)	5	*Portunus gibbesii* (Ar)	4	*Scophthalmus aquosus* (Ch)	3	*Prionotus carolinus* (Ch)	10
Crepidula plana (Mo)	5	*Cynoscion regalis* (Ch)	3	*Penaeus aztecus aztecus* (Ar)	3	*Pagurus pollicaris* (Ar)	10
Crepidula fornicata (Mo)	5	*Leiostomus xanthurus* (Ch)	3	*Pagurus longicarpus* (Ar)	3	*Mellita quinquesperforata* (Ech)	10
Leiostomus xanthurus (Ch)	4	*Trachypenaeus constrictus* (Ar)	3	*Pagurus pollicaris* (Ar)	3	*Leiostomus xanthurus* (Ch)	9
Hepatus epheliticus (Ar)	4	*Callinectes similis* (Ar)	3	*Ovalipes stephensoni* (Ar)	3	*Balanus venustus* (Ar)	9
Portunus gibbesii (Ar)	4	*Halecium* sp. (Cn)	3	*Portunus gibbesii* (Ar)	3	*Membranipora arborescens* (Bry)	9
Balanus venustus (Ar)	4	*Mellita quinquesperforata* (Ech)	3	*Balanus venustus* (Ar)	3	*Crepidula fornicata* (Mo)	9
Astropecten duplicatus (Ech)	4	*Membranipora tenuis* (Bry)	3	*Mellita quinquesperforata* (Ech)	3	*Scophthalmus aquosus* (Ch)	8
Mellita quinquesperforata (Ech)	4			*Membranipora arborescens* (Bry)	3	*Hepatus epheliticus* (Ar)	8
Membranipora tenuis (Bry)	4			*Crepidula fornicata* (Ar)	3	*Calliactis tricolor* (Cn)	8
Membranipora arborescens (Bry)	4			*Raja eglanteria* (Ch)	2	*Membranipora tenuis* (Bry)	8
Prionotus carolinus (Ch)	3			*Larimus fasciatus* (Ch)	2	*Crepidula plana* (Mo)	8
Scophthalmus aquosus (Ch)	3			*Stellifer lanceolatus* (Ch)	2	*Micropogonias undulatus* (Ch)	7
Symphurus plagiusa (Ch)	3			*Symphurus plagiusa* (Ch)	2	*Penaeus aztecus aztecus* (Ar)	7
Ovalipes ocellatus (Ar)	3			*Tenaciella obliqua* (Po)	2	*Trachypenaeus constrictus* (Ar)	7
Portunus spinimanus (Ar)	3			*Trachypenaeus constrictus* (Ar)	2	*Pagurus longicarpus* (Ar)	7
Callinectes sapidus (Ar)	3			*Hepatus epheliticus* (Ar)	2	*Ovalipes ocellatus* (Ar)	7
Squilla empusa (Ar)	3			*Ovalipes ocellatus* (Ar)	2	*Lolliguncula brevis* (Mo)	7
Hydractinia echinata (Cn)	3			*Arenaeus cribrarius* (Ar)	2		
Astrangia astreiformis (Cn)	3			*Leiostomus xanthurus* (Ch)	2		
Arbacia punctulata (Ech)	3			*Callinectes* sp. (Ar)	2		
Parasmittina nitida (Mo)	3			*Calliactis tricolor* (Cn)	2		
Reptadeonella hastingsae (Mo)	3			*Crepidula plana* (Mo)	2		
Lolliguncula brevis (Mo)	3			*Lolliguncula brevis* (Mo)	2		
				Sargassum natans (Al)	2		

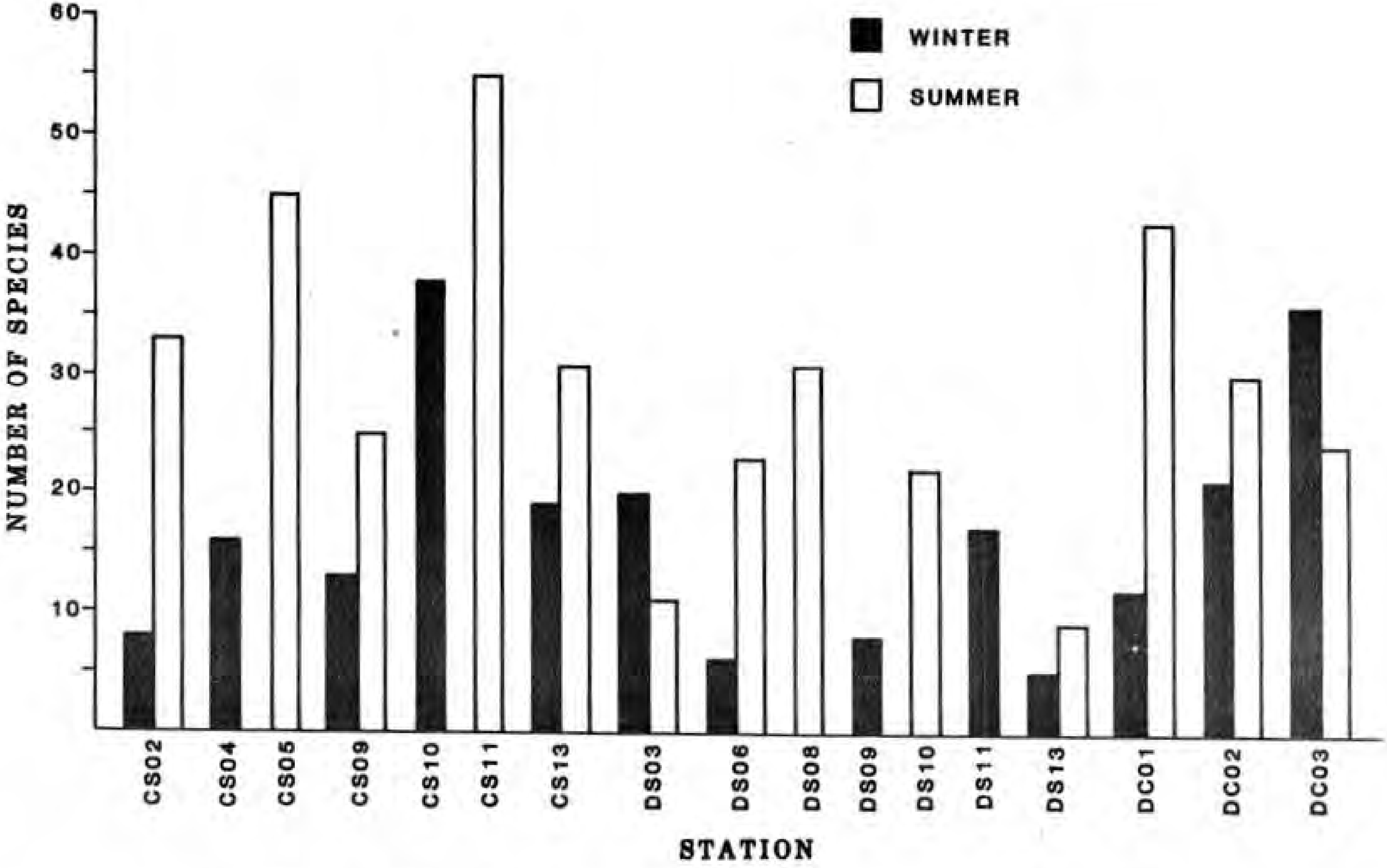


Figure 15. Number of species collected at each station by beam trawl. Stations which were sampled during only one season are represented by a single bar.

numbers of tows were made in the disposal and control areas, whereas the "down current" area was sampled less frequently. These data suggest that the diversity of invertebrates and fishes collected by trawl was lower in the disposal area. Van Dolah et al. (1983) also found fewer species in the disposal area near Charleston Harbor, but attributed the lower total number of invertebrate species there to the smaller number of stations sampled rather than to any disposal effects. Examination of species lists from the present study (Appendix 4) indicated that a greater number of bryozoans and cnidarians were present in collections from control and "down current" sites than in the DMDS. The increased number of these sessile taxa is probably related to the patchy occurrence of hard substrate, primarily shell and wood, suitable for colonization at those sites. There was no evidence of extensive hard bottom at any of the sites, and consequently, the total number of invertebrate taxa (126 species) was considerably lower than that reported for hard bottom areas farther offshore in the South Atlantic Bight (Wenner et al., 1983). Values of *e*, however, were comparable to those reported by Hinde et al. (1981) and Van Dolah et al. (1983). On the other hand, the number of fishes collected (28 species) was much lower than previously reported for Winyah Bay (Wenner et al., 1981; Hinde et al., 1981; Allen et al., 1982) or the nearshore coastal region of the South Atlantic Bight (C. Wenner, pers. comm.). The low number of fish species in beam trawl collections probably resulted from their ability to avoid the sampling gear. The narrow mouth opening, slow-towing speed, and small area swept by the beam trawl makes it an inefficient method of collecting fish, many of which are found higher in the water column or can outswim this gear.

Comparisons of mean biomass between areas and seasons revealed no significant difference for either factor ($F_{season[1,2]} = 2.205$, $F_{area[2,2]} = 0.401$; $P > 0.05$) (Table 10). Based on 3-m mouth spread and a tow distance of 503 m, the area swept by the beam trawl was calculated to be 0.15 hectare/tow. Total biomass estimates (kg/ha) for the areas sampled during our study area were:

	winter	summer
Control Stations	8.4	19.1
Disposal Stations	12.3	9.2
"Down Current" Stations	7.5	26.2

Wenner et al. (1981) obtained lower values for biomass of decapod crustaceans and fishes in the Winyah Bay system. However, Hoese (1973) reported values of 10.7 kg/ha for fishes and 6.1 kg/ha for invertebrates in Doboy Sound, Georgia. In the nearshore and coastal habitat of the South Atlantic Bight, biomass estimates for fishes of 23 kg/ha have been obtained in winter and 12 kg/ha in summer (C. Wenner, pers. comm.). Undoubtedly, higher estimates of total biomass would have been obtained if a sampling gear which was more effective in capturing fish had been used.

Normal cluster analysis of data resulting from beam trawl collections identified five distinct site groups based on similarity of faunal composition (Figure 16). There was no tendency for stations to be grouped according to area since all groups contained stations located both inside and outside the disposal area boundaries. However, stations were grouped by season indicating that species composition in the study area was different between winter and summer.

Inverse cluster analysis of the 81 species which occurred in two or more collections produced 11 groups (Table 11). Nodal diagrams were used to describe the distribution of species in terms of their relative constancy and fidelity to site groups (Figure 17). As indicated by nodal analysis, species in group A were highly restricted but only moderately constant at stations in site group 5, which were sampled primarily in winter (with the exception of CS11). Species in this group are common inhabitants of the nearshore coastal habitat, but are apparently restricted in their distribution. For example, *Busycon carica*, the species chosen for pollutant-uptake assessment, was collected at only two stations, CS05 and DC03. The spotted hake, *Urophycis regius*, was limited in both its spatial and temporal distribution, being collected only at "down current" stations in winter (Appendix 4).

Group B included three species which were neither consistently collected nor restricted to stations in any site group. The rock crab, *Cancer irroratus*, which is a common inhabitant of coastal waters off the New England and Middle Atlantic states (Williams, 1965) was collected only during winter sampling.

Species in Group C were also neither very constant nor faithful to stations in any site group; however, every species in this group except *Busycon canaliculata* was collected exclusively in the control area. Two species in this group, the bryozoan *Hippaliosina rostrigera* and the starfish Asteroidea A, were collected only in summer.

Group D is comprised of species which were fairly ubiquitous throughout the study area but were consistently collected only at stations in groups 2 and 5. These species were also well represented in collections from both seasons, with *Chama macerophylla* being the only species which occurred solely in summer (Appendix 4).

Group E contained species which are common inhabitants of the nearshore coastal habitat in the South Atlantic Bight. These species were most consistently collected during summer at stations in group 1. Those species which were collected exclusively during summer

Table 10. Summary of biomass (kg) for organisms collected with the beam trawl.

	Winter	Summer
Control Stations	$\bar{x} = 1.26$	$\bar{x} = 2.87$
	$S_{\bar{x}} = 0.54$	$S_{\bar{x}} = 0.51$
	$n = 5$	$n = 5$
Disposal Stations	$\bar{x} = 1.844$	$\bar{x} = 1.38$
	$S_{\bar{x}} = 0.64$	$S_{\bar{x}} = 0.58$
	$n = 5$	$n = 5$
Down-Current Stations	$\bar{x} = 1.13$	$\bar{x} = 3.93$
	$S_{\bar{x}} = 0.61$	$S_{\bar{x}} = 1.52$
	$n = 3$	$n = 3$

Table 14. Relative abundance of the ten dominant species at each site during each season. FT indicates the feeding type of each species (C = carnivore, D = deposit feeder, O = omnivore, S = suspension-feeder) and the numerical values represent the percentage contribution of each species to the total number at that site in a particular season.

CONTROL STATIONS			DISPOSAL STATIONS			DOWN-CURRENT STATIONS			COMBINED STATIONS		
FT	%	Species Name	FT	%	Species Name	FT	%	Species Name	FT	%	Species Name
					WINTER						
S	13.9	*Ensis directus*	S	40.6	*Ensis directus*	S	60.9	*Ensis directus*	S	26.2	*Ensis directus*
S	6.8	*Crassinella lunulata*	S	18.1	*Crassinella martinencis*	?	11.1	Polygordiidae A	S	6.8	*Crassinella martinicensis*
D	6.1	*Batea catharinensis*	S	5.9	*Pleuromeris tridentata*	C,D	5.1	Nematoda	S	5.0	*Crassinella lunulata*
S	5.7	*Erichthonius brasiliensis*	S	3.3	*Sabellaria vulgaris*	C	2.1	Nemertinea	?	4.6	Polygordiidae A
?	4.7	Polygordiidae A	S	3.1	*Pyura vittata*	D	1.5	*Polycirrus eximius*	D	3.8	*Batea catharinensis*
C,D	3.7	Nematoda	S	2.7	*Crassinella lunulata*	C	1.4	*Nephtys picta*	S	3.7	*Erichthonius brasiliensis*
S	3.2	*Crassinella martinicensis*	D	2.3	*Acanthohaustorius millsi*	S	1.2	*Sabellaria vulgaris*	C,D	3.3	Nematoda
C	3.0	Nemertinea	C,D	1.6	Nematoda	O	1.2	*Ancinus depressus*	C	2.5	Nemertinea
D	2.6	*Aspidosiphon gosnoldi*	?	1.4	Polygordiidae A	C	0.8	*Glycera* sp. A	D	2.0	*Aspidosiphon gosnoldi*
O	2.3	*Exogone dispar*	D	1.3	*Aspidosiphon gosnoldi*	D	0.8	*Nerinides unidentata*	S	1.8	*Pyura vittata*
					SUMMER						
C,D	7.4	Nematoda	S	25.8	*Cupuladria doma*	S	26.9	*Cupuladria doma*	S	17.6	*Cupuladria doma*
D	6.4	*Mediomastus californiensis*	S	21.9	*Crassinella martinicensis*	S	6.8	*Ensis directus*	S	12.5	*Crassinella martinicensis*
S	6.2	*Ensis directus*	S	9.5	*Pyura vittata*	S	6.3	*Pyura vittata*	S	7.2	*Pyura vittata*
S	4.9	*Crassinella lunulata*	S	3.5	*Sabellaria vulgaris*	D	5.8	*Paraprionospio pinnata*	S	3.8	*Ensis directus*
D	4.9	*Paraprionospio pinnata*	S	3.4	*Crassinella lunulata*	S	2.8	*Crassinella martinicensis*	S	3.7	*Crassinella lunulata*
S	4.9	*Cupuladria doma*	D	2.3	*Aspidosiphon gosnoldi*	D	2.7	*Magelona phyllisae*	D	3.5	*Mediomastus californiensis*
S	4.5	*Pyura vittata*	S	2.1	*Pleuromeris tridentata*	D	2.7	Oligochaeta	C,D	3.3	Nematoda
S	3.4	*Crassinella martinicensis*	D	1.9	Oligochaeta	C	2.4	*Nephtys picta*	D	2.6	*Paraprionospio pinnata*
D	2.8	Oligochaeta	S	1.8	*Discoporella umbellata*	S	2.4	*Sabellaria vulgaris*	S	2.4	*Sabellaria vulgaris*
O	2.5	*Amphiodia pulchella*	D	1.7	*Mediomastus californiensis*	C	2.3	Nemertinea	D	2.3	Oligochaeta

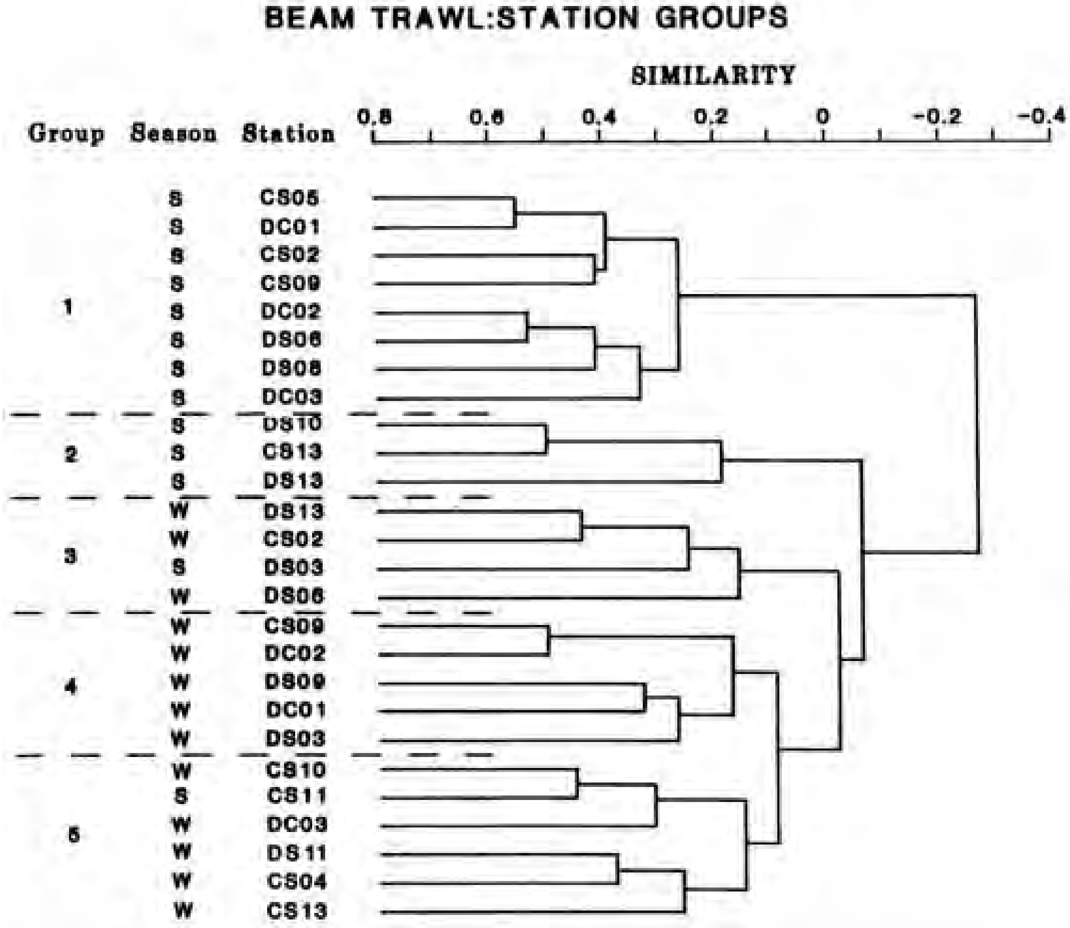


Figure 16. Normal cluster dendrogram showing station groups formed using the Jaccard similarity coefficient and flexible sorting of beam trawl collections.

Table 11. Species groups resulting from numerical classification of data from samples collected by beam trawl. (Al = Algae; Ar = Arthropoda; Bry = Bryozoa; Ch = Chordata; Cn = Cnidaria; Ech = Echinodermata; Mo = Mollusca; Po = Porifera).

Group A

- *Pilumnus sayi* (Ar)
- *Telesto fruticulosa* (Cn)
- Actiniaria A (Cn)
- *Asterias forbesii* (Ech)
- *Squilla empusa* (Ar)
- *Urophycis regius* (Ch)
- *Busycon carica* (Mo)

Group B

- *Cancer irroratus* (Ar)
- *Neopanope sayi* (Ar)
- *Aplidium constellatum* (Ch)

Group C

- *Hippoporina contracta* (Bry)
- *Hippaliosina rostrigera* (Bry)
- *Centropristis striata* (Ch)
- *Lytechinus variegatus* (Ech)
- Asteroidea A (Ech)
- *Arbacia punctulata* (Ech)
- *Astropecten duplicatus* (Ech)
- *Busycon canaliculata* (Mo)

Group D

- *Reptadeonella hastingsae* (Bry)
- *Parasmittina nitida* (Bry)
- *Portunus spinimanus* (Ar)
- *Membranipora tenuis* (Bry)
- *Astrangia astreiformis* (Cn)
- *Etropus crossotus* (Ch)
- *Schizoporella errata* (Bry)
- *Hippoporina verrilli* (Bry)
- *Chama macerophylla* (Mo)
- *Electra monostachys* (Bry)

Group E

- *Micropogonias undulatus* (Ch)
- *Arenaeus cribrarius* (Ar)
- *Pagurus longicarpus* (Ar)
- *Cynoscion regalis* (Ch)
- *Callinectes similis* (Ar)
- *Hepatus epheliticus* (Ar)
- *Larimus fasciatus* (Ch)
- *Penaeus aztecus aztecus* (Ar)
- *Stellifer lanceolatus* (Ch)
- *Sclerodactyla briareus* (Ech)
- *Sargassum natans* (Al)
- *Aplidium* sp. (Ch)
- *Rhinoptera bonasus* (Ch)

Group F

- *Mellita quinquesperforata* (Ech)
- *Prionotus carolinus* (Ch)
- *Pagurus pollicaris* (Ar)
- *Membranipora arborescens* (Bry)
- *Balanus venustus* (Ar)
- *Crepidula plana* (Mo)
- *Calliactis tricolor* (Cn)
- *Crepidula fornicata* (Mo)
- *Leiostomus xanthurus* (Ch)

Group G

- *Symphurus plagiusa* (Ch)
- *Ovalipes ocellatus* (Ar)
- *Scophthalmus aquosus* (Ch)
- *Brevoortia tyrannus* (Ch)
- *Anchoa mitchilli* (Ch)
- *Ovalipes stephensoni* (Ar)
- *Portunus gibbesii* (Ar)
- *Trachypenaeus constrictus* (Ar)
- *Libinia emarginata* (Ar)
- *Halecium* sp. (Cn)

Group H

- *Tenaciella obliqua* (Po)
- *Trinectes maculatus* (Ch)
- Ascidiacea A (Ch)
- *Limulus polyphemus* (Ar)
- *Epizoanthus americanus* (Cn)

Group I

- *Raja eglanteria* (Ch)
- *Hexapanopeus angustifrons* (Ar)
- *Acetes americanus* (Ar)
- *Persephona mediterranea* (Ar)
- *Citharichthys macrops* (Ch)
- *Callinectes sapidus* (Ar)
- *Porcellana sayana* (Ar)

Group J

- *Lolliguncula brevis* (Mo)
- *Hydractinia echinata* (Cn)
- *Penaeus setiferus* (Ar)
- *Menippe mercenaria* (Ar)

Group K

- *Microporella ciliata* (Bry)
- *Polinices duplicatus* (Mo)
- *Ancylopsetta quadrocellata* (Ch)
- *Trypostega venusta* (Bry)
- *Eupleura caudata* (Mo)

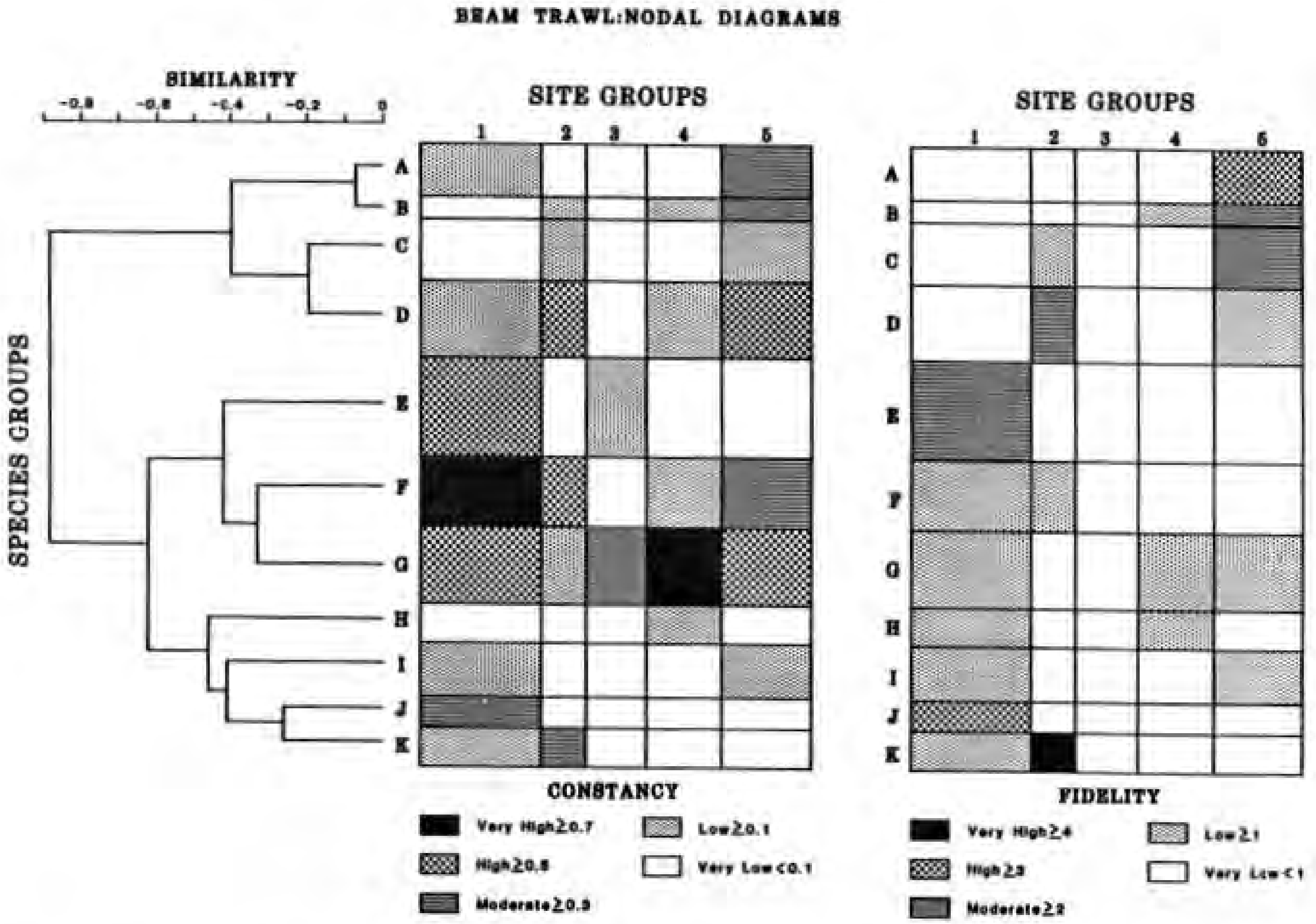


Figure 17. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on beam trawl collections.

included the Atlantic croaker, *Micropogonias undulatus*; the grey trout, *Cynoscion regalis*; the banded drum, *Larimus fasciatus*; the cownose ray, *Rhinoptera bonasus*; the portunid crabs *Callinectes similis* and *Arenaeus cribrarius*; the brown shrimp, *Penaeus aztecus aztecus*; and the brown alga *Sargassum natans*.

Groups F and G contained species which were generally ubiquitous throughout the study area and, therefore, not faithful to any particular site group. Group F species were most consistently collected during summer at stations in groups 1 and 2. Two species, *Prionotus carolinus* and *Calliactis tricolor*, were collected only in summer. Species in Group G were those which were frequently collected at most stations during both seasons. The most frequently encountered species in the study (*Ovalipes stephensoni*, *Portunus gibbesii*, *Halecium* sp., and *Trachypenaeus constrictus*) occurred in this group. The only species in Group G which was temporaly restricted was *Brevoortia tyrannus*, the Atlantic menhaden, which occurred only in winter.

Groups H and I included infrequently collected species which were not very constant or faithful to any site group. In these groups, the sponge *Tenaciella obliqua*; the fishes *Trinectes maculatus* and *Raja eglanteria*; and the decapods *Hexapanopeus angustifrons*, *Acetes americanus* and *Persephona mediterranea* were collected only in summer, while the horseshoe crab, *Limulus polyphemus*, and the anemone *Epizoanthus americanus* were collected only in winter.

Species in groups J and K were highly faithful to stations comprising site groups 1 and 2, respectively; however, they were not consistently collected at those stations. These two groups constitute a summer assemblage of organisms in the study area, with all members except the flounder *Ancylopsetta quadrocellata* and the bryozoans *Microporella ciliata* and *Tryptostega venusta* occurring exclusively in summer collections.

In conclusion, the community structure of fishes and epifaunal invertebrates in the study area is influenced by seasonality. The number of species was significantly higher in summer. Furthermore, species assemblages differed noticeably between winter and summer, with several species occurring during only one season. Although the total number of species was lowest in the disposal area, comparisons of species composition between sites indicated that lower diversity resulted from fewer sessile organisms, mainly bryozoans and cnidarians. This suggests that less substrate was available for colonization by sessile organisms in the sampled portions of the disposal area. However, lesser amounts of substrate such as wood and shell in the DMDS are probably not related to past disposal activities.

Grab Collections

Grab samples from control, disposal, and "down current" stations yielded more than 19,000 individuals representing at least 357 species of invertebrates (Tables 12, 13; Appendices 5-10). More species and individuals were collected from the control site than from disposal or "down current" stations (Tables 12 and 13). Collections from "down current" stations yielded considerably fewer species and individuals than control or disposal sites, but this reflects, in part, the reduced sampling effort in that area (three stations versus five at CS and DS areas).

The number of species collected during the present study was considerably higher than that collected for the Savannah, Charleston, and Wilmington DMDS study (SCW-DMDS; US EPA, 1982). In that relatively limited survey, only 28, 82 and 30 species were found in and adjacent to those disposal areas, respectively. However, a more intensive study of the Charleston DMDS (Van Dolah et al., 1983) reported the occurrence of 439 species, indicating that diversity in sand bottom habitats of South Carolina coastal waters may typically be much higher than previously reported. Knott et al. (1983b) also reported collecting a large number of species (205) in shallower water off the beaches near Murrells Inlet, South Carolina.

Overall, polychaetes were the most well represented group of the 27 higher taxa identified, with 152 species accounting for 43% of the total number of species (Table 12, Figure 18). Polychaetes also accounted for a similar proportion of the number of species within each of the sites sampled (control, disposal, and "down current"). Amphipods, pelecypods (42 species each), gastropods (36 species), and decapods (33 species) were the other diverse taxa and together with the polychaetes comprised about 85% of the total number of species. Only minor differences occurred between control, disposal and "down current" sites with respect to the proportional contribution of these major taxa (Figure 18). The relative importance of these taxonomic groups was also very similar to that observed in the Charleston DMDS, where polychaetes contributed 43% and the same five dominant taxa contributed 82% of the total number of species (Van Dolah et al., 1983).

In terms of numerical abundance, pelecypods were dominant when all stations were considered together (34%). Pelecypods were also the most abundant organisms at disposal and "down current" stations (Table 13, Figure 18). At control stations, however, pelecypods ranked second to polychaetes, and amphipods were relatively more important than at the other sites. Additionally, the relative abundance of lunulitiform bryozoan colonies noted at disposal and "down current" stations was not apparent within the control site. It should be noted that these bryozoans were sorted and identified

Table 12. Number of species representing each of the major macroinvertebrate taxa in grab samples from control, disposal, and "down current" sites. (* indicates a taxon that was probably represented by more species than indicated due to uncertain or incomplete identifications).

	CONTROL STATIONS		DISPOSAL STATIONS		DOWN CURRENT STATIONS		COMBINED STATIONS	
Taxa	Number of Species	Rank	Number of Species	Rank	Number of Species	Rank	Number of Species	Rank
Polychaeta	116	1	94	1	58	1	152	1
Amphipoda	37	2	22	3	16	2.5	42	2.5
Pelecypoda	30	4	30	2	16	2.5	42	2.5
Gastropoda	31	3	12	5	7	5	36	4
Decapoda	29	5	16	4	12	4	33	5
Echinodermata	7	6	5	7	2	7	9	6
Isopoda	4	9.5	6	6	1	16	7	7
Mysidacea	5	7	4	8	3	6	5	8
Sipunculida*	4	8	3	9	1	16	4	9
Cumacea	4	9.5	1	20.5	1	16	4	10
Anthozoa*	3	11	2	11	1	95	3	11
Bryozoa	2	13	3	10	1	16	3	12
Hemichordata*	2	13	1	20.5	1	16	2	13
Scaphapoda	2	13	-	-	-	-	2	14
Nemertina*	1	17	1	14	1	9.5	1	15
Oligochaeta*	1	17	1	14	1	9.5	1	16
Turbellaria*	1	17	1	14	-	-	1	17
Nematoda*	1	17	1	14	1	9.5	1	18
Ostracoda*	1	17	1	14	1	16	1	19
Tanaidacea	-	-	1	20.5	-	-	1	20
Ascidiacea	1	23	1	20.5	1	16	1	21
Brachiopoda	1	23	1	20.5	-	-	1	22
Cephalochordata	1	23	1	20.5	1	16	1	23
Stomatopoda	1	23	1	20.5	-	-	1	24
Echiurida	1	23	-	-	1	16	1	25
Pycnogonida	1	23	1	20.5	-	-	1	26
Phoronida	1	23	-	-	-	-	1	27
Total	288		210		127		357	

Table 13. Number of individuals representing each of the major macroinvertebrate taxa in grab samples from control, disposal, and "down current" sites. (* = bryozoans were not enumerated in winter samples).

	CONTROL STATIONS		DISPOSAL STATIONS		DOWN CURRENT STATIONS		COMBINED STATIONS	
Taxa	Total Number	Rank	Total Number	Rank	Total Number	Rank	Total Number	Rank
Pelecypoda	2337	2	3197	1	893	1	6427	1
Polychaeta	3159	1	1031	3	550	2	4740	2
Amphipoda	1490	3	330	5	81	4	1901	3
Bryozoa*	204	11	1198	2	247	3	1649	4
Ascidiacea	255	8	498	4	64	6	817	5
Nematoda	498	4	88	9	67	5	653	6
Decapoda	421	5	109	7	50	7	580	7
Echinodermata	309	6	76	10	24	11	409	8
Sipunculida	245	9	151	6	10	13	406	9
Nemertinea	271	7	74	11	46	8	391	10
Oligochaeta	196	12	93	8	31	9	320	11
Gastropoda	239	10	27	14	16	12	282	12
Cumacea	113	13	26	15	2	17	141	13
Anthozoa	105	14	10	18	4	16	119	14
Isopoda	23	16	51	12	26	10	100	15
Mysidacea	43	15	47	13	7	14.5	97	16
Turbellaria	18	17	2	21	-	-	20	17
Tanaidacea	-	-	18	16	-	-	18	18
Cephalochordata	3	21	12	17	1	19	16	19
Hemichordata	3	21	3	19	7	14.5	13	20
Ostracoda	7	18	2	21	1	19	10	21
Stomatopoda	5	19	1	23.5	-	-	6	22
Brachiopoda	3	21	2	21	-	-	5	23
Echiurida	2	23.5	-	-	1	19	3	24
Pycnogonida	1	25.5	1	23.5	-	-	2	25.5
Scaphapoda	2	23.5	-	-	-	-	2	25.5
Phoronida	1	25.5	-	-	-	-	1	27
Total	9953		7047		2128		19128	

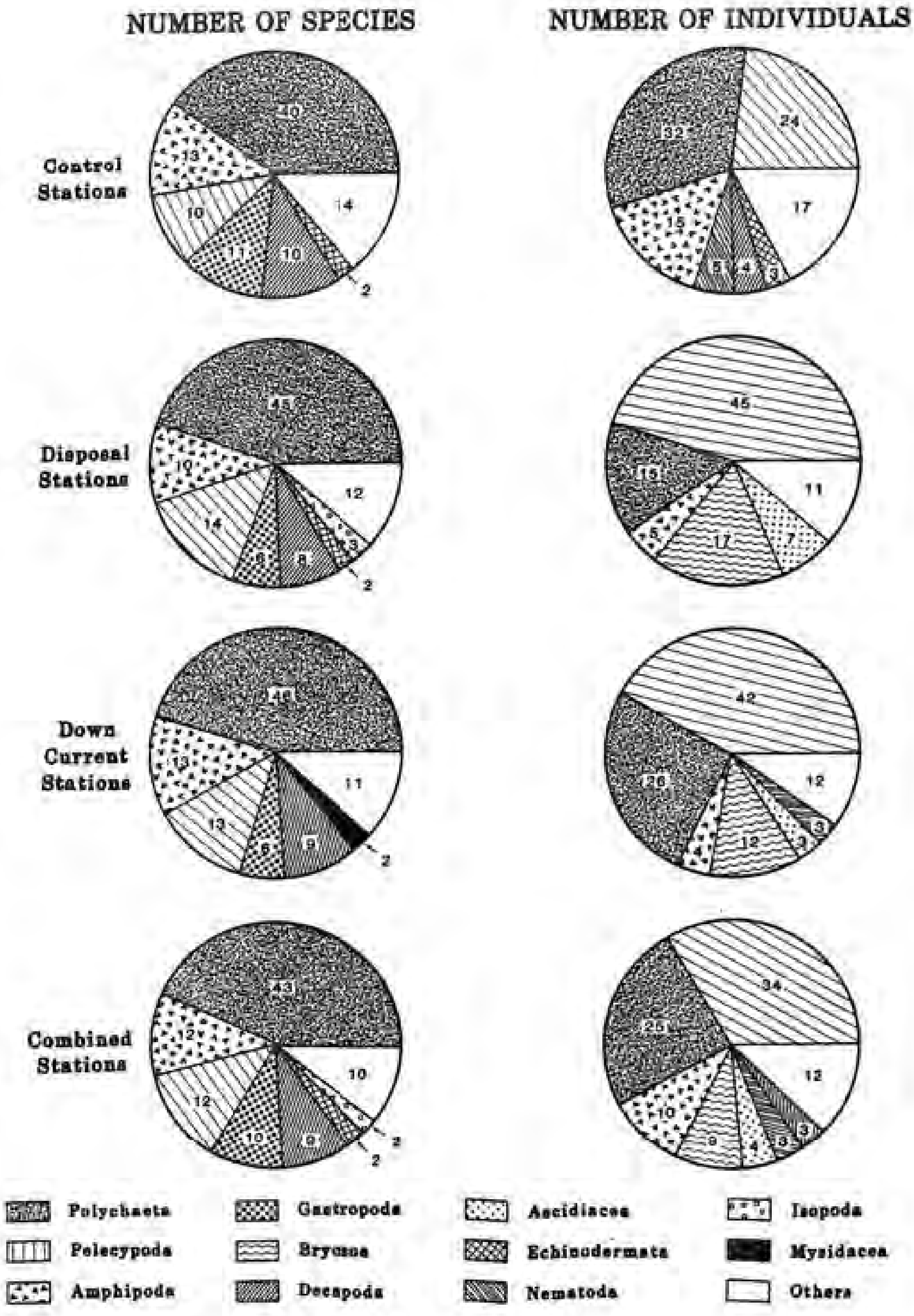


Figure 18. Percentage contribution of major taxa to the number of species and number of individuals in grab samples from control, disposal, and "down current" sites. The number of individuals noted for bryozoans refers to the number of colonies.

only from samples collected during the summer season. For this reason, their abundance at each site may be somewhat underestimated, although comparisons between sites should be valid, nonetheless.

The relative abundance of different major taxa collected from the Georgetown DMDS was somewhat different than that reported by Van Dolah et al. (1983) for the Charleston DMDS. Off Charleston, polychaetes (37%) were conspicuously more abundant than pelecypods (7%), and cephalochordates (20%) and sipunculids (5%) represented a considerable portion of the total number of organisms.

In the Georgetown DMDS study area, we noted temporal and spatial variation in the dominant species (top 10 in abundance) (Table 14). The razor clam, *Ensis directus*, was the most abundant species at each site during the winter, with more than twice as many specimens collected than the next most abundant species. In summer samples, this dominance by *E. directus* was no longer apparent, and the lunulitiform bryozoan *Cupuladria doma* was the most abundant species at disposal and "down current" stations. Nematodes were numerically dominant at control stations. Since *C. doma* was not processed in winter samples, these apparent seasonal changes in dominance may not be real. However, it should be noted that five species (the pelecypods *E. directus*, *Crassinella martinicensis*, and *Crassinella lunulata*; the solitary ascidian *Pyura vittata*; and nematodes) were among the ten most abundant collected during both seasons (Table 14).

Many of the dominant species were widely distributed throughout the study area (Table 14) and none were restricted to a particular site. The disposal and "down current" sites were numerically dominated by one or two species during each season. At the control site, however, there was a more even distribution of individuals among several species.

Two taxa common at the control site, the capitellid polychaete *Mediomastus californiensis* and nematodes, are deposit feeders, while suspension feeding animals were dominant at all other sites (Table 14). In fact, suspension feeders accounted for at least 51% of the total number of animals from the entire study area. The actual percentage may be greater than this, since only known suspension feeders that contributed more than 0.1% of the total number of organisms were considered.

In contrast to the suspension feeding community observed in the Georgetown DMDS, the SCW-DMDS were characterized as being primarily composed of small-bodied deposit feeders (often polychaetes and crustaceans) (US EPA, 1982). That study also noted that in the Charleston disposal site suspension feeders typically accounted for fewer than 20% of the individuals. Van Dolah et al. (1983), however, collected large numbers of the suspension-feeding cephalochordate *Branchiostoma caribaeum* in the Charleston DMDS. This species, together with filter-feeding pelecypods and bryozoans, accounted for nearly 30% of the total number. Thus, it appears that the suspension-feeding component of macrobenthic communities in some nearshore environments may be more important than previously indicated (US EPA, 1982).

To evaluate the effects of seasonality on numerical dominance and areal distribution of important species, the mean density of each species which contributed greater than 1% of the total number of individuals was plotted against station location and season (Figure 19). Actual values for each species are listed in Table 15. Appendices 5-10 indicate a high degree of variability among replicates and stations within each site and season. Similar temporal and spatial variability is common among macrobenthic communities of the South Atlantic Bight (Frankenberg and Leiper, 1977; US EPA, 1982; Knott et al., 1983a).

Three species were conspicuous when compared to the others because they were considerably more abundant. *Ensis directus*, *C. martinicensis*, and *C. doma* were far more numerous than all other species (note the difference in scale of the top row of histograms, Figure 19). The most abundant species, *E. directus*, is a common shallow-water inhabitant along the entire Atlantic Coast (Theroux and Wigley, 1983). It was found in significantly greater numbers at all sites during the winter ($P < 0.001$, ANOVA), probably due to spawning activity during this season. Knott et al. (1983a) noted a single spawning of this species sometime between November and February. The reproductive cycle of *E. directus* should be considered in determining the optimal schedule of release of dredged material in this area since Harrison et al. (1964) reported that its larval dispersal and settlement helped to mitigate the effects of defaunation caused by dredging and spoil disposal in the lower Chesapeake Bay.

Mean densities of *E. directus* were not significantly different between sites ($P > 0.05$), nor were significant differences ($P > 0.05$) noted between sites in the mean densities of the second and third most abundant species, *C. martinicensis* and *C. doma*. These species however, both had higher densities in the disposal site than elsewhere (Figure 19). Both of these are typically free-living species found in coarse, shelly sand of shallow coastal waters (Harry, 1966; Winston, 1982). *Cupuladria doma* was also among the dominant species in the Charleston DMDS (Van Dolah et al., 1983).

Another species of *Crassinella* (*C. lunulata*) was the fourth most abundant species overall.

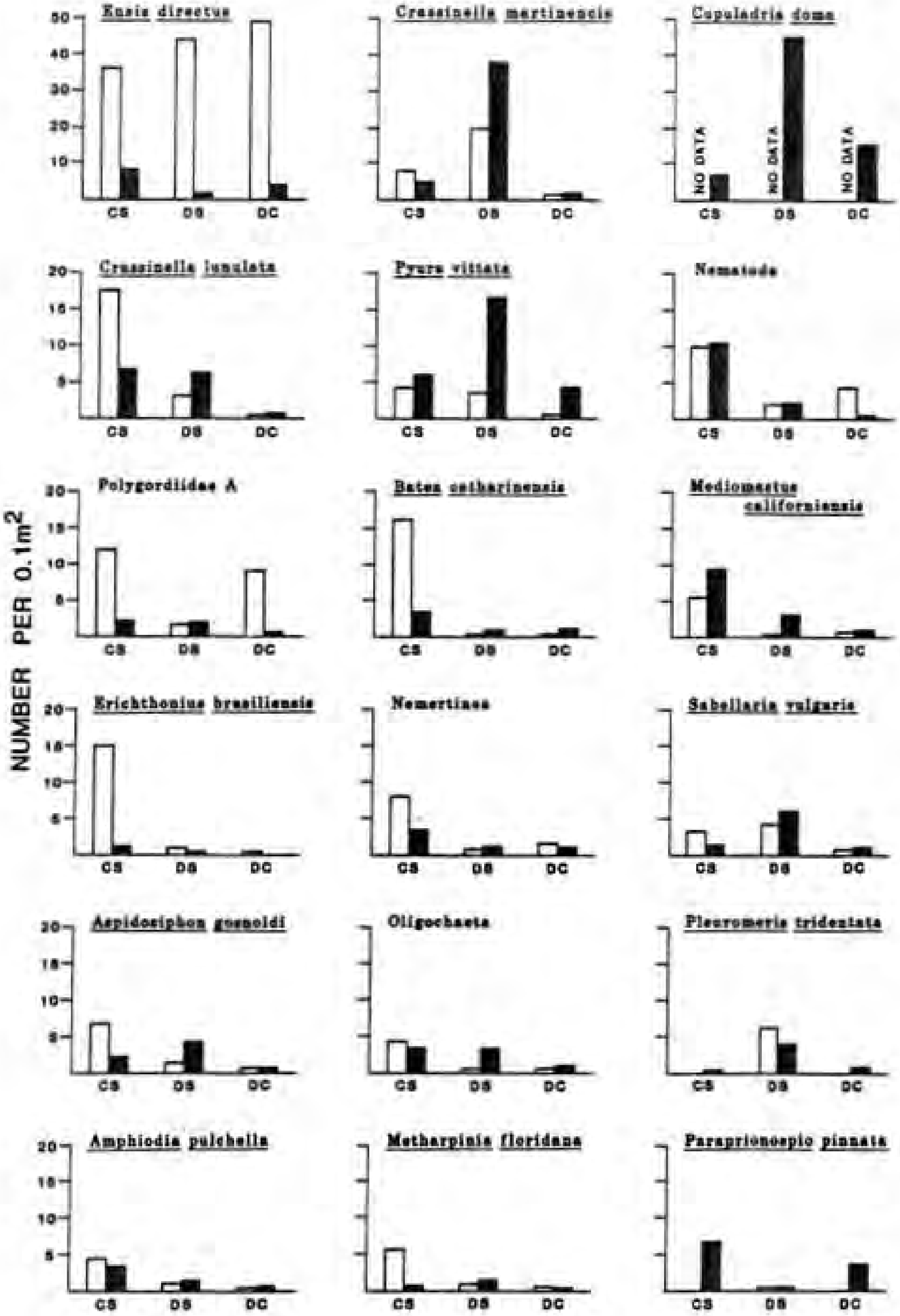


Figure 19. Comparison of the mean density of dominant macroinvertebrates from grab samples at control (CS), disposal (DS), and "down current" (DC) sites. Only species represented by more than 1% of the total number of individuals are included. (Open bars are winter, solid bars are summer).

Table 15. Mean density of the dominant macroinvertebrates at control, disposal, and "down current" sites during each season. Values are the number of individuals per 0.1 m^2.

	CONTROL STATIONS		DISPOSAL STATIONS		DOWN CURRENT STATIONS	
	WINTER Mean Density	SUMMER Mean Density	WINTER Mean Density	SUMMER Mean Density	WINTER Mean Density	SUMMER Mean Density
Ensis directus	36.4	8.6	44.1	2.1	49.2	4.1
Crassinella martinicensis	8.4	4.7	19.7	38.0	0.6	1.7
Cupuladria doma	no data	6.8	no data	44.8	no data	16.5
Crassinella lunulata	17.9	6.8	2.9	5.9	0.1	0.2
Pyura vittata	3.9	6.3	3.4	16.6	0.4	3.9
Nematoda	9.6	10.3	1.7	1.8	4.1	0.3
Polygordiidae A	12.3	2.1	1.5	1.6	8.9	0.5
Batea catharinensis	15.9	2.9	t	0.8	0.1	1.1
Mediomastus californiensis	5.4	8.8	0.1	2.9	0.4	1.0
Erichthonius brasiliensis	15.0	1.6	0.4	0.2	0.2	0
Nemertinea	7.9	2.9	1.4	1.6	1.7	1.4
Sabellaria vulgaris	2.9	1.4	3.6	6.0	1.0	1.5
Aspidosiphon gosnoldi	6.8	2.2	1.4	4.0	0.3	0.3
Oligochaeta	4.0	3.8	0.4	3.3	0.4	1.7
Pleuromeris tridentata	0	0.2	6.4	3.7	0	0.5
Amphiodia pulchella	4.1	3.5	0.7	1.0	0.3	0.5
Metharpinia floridana	5.5	0.7	1.2	1.5	0.2	0.1
Paraprionospio pinnata	0	6.8	t	0.2	0	3.5

This bivalve typically spends most of its time on the top of the substrate rather than buried in it, climbing on bits of shell by means of its foot and delicate byssal threads (Harry, 1966). It has previously been reported as an important member of the benthic macrofauna in the entrance channel of Winyah Bay (Hinde et al., 1981), where it was largely restricted to sandy sediment. In the present study, it was significantly more dense in the control site than at the disposal and "down current" stations during winter sampling ($P < 0.02$), although no such pattern was observed among collections taken during the summer (Figure 19).

The fifth most abundant species was the solitary ascidian, *Pyura vittata*. This small ascidian is found in shallow water attached to small bits of shell or stone (Van Name, 1945; Plough, 1978). Its pattern of density among our stations resembled that of *C. martinicensis* and *C. doma*, in that it was most common in the summer in the disposal site (Figure 19). Like those species, however, this pattern was not statistically significant ($P > 0.05$). Comparisons of mean densities among sites and seasons for the remaining dominant species resulted in only one other significant difference. During both seasons, the polychaete *Mediomastus californiensis* was more abundant at control stations than elsewhere (Figure 19), and in winter the difference between CS stations and DS stations was significant ($P < 0.05$).

The two most abundant macroinvertebrates collected in the Charleston DMDS were the lancelet *Branchiostoma caribaeum* and the sipunculid *Aspidosiphon gosnoldi* (reported as *A. spinalis*; Van Dolah et al., 1983). Although *A. gosnoldi* was also found in higher densities in the Georgetown DMDS (Figure 19), *B. caribaeum* was not nearly as common (Appendices 5–10). This difference between the two disposal sites is noteworthy, although not easily explained. It could be due, in part, to the relative mobility of the lancelet, which is often taken in surface water samples (Boschung and Gunter, 1962), and to differences in the availability of suitable shell substrate, which is necessary for large populations of the nestling sipunculid (Cutler, 1973).

The spionid polychaete *P. pinnata*, which was abundant during the summer in the control and "down current" sites, was also among the dominant species collected during October in the entrance channel to Winyah Bay (Hinde et al., 1981). In that study, it was found in finer sediments of the channel (> 93% silt and clay), and in another study of dredge spoil disposal effects it appears to have been transported to the disposal site via dredged material (Van Dolah et al., 1979).

The diversity of the benthic communities was compared among sites and seasons using several indices of community structure (Appendix 11). To facilitate this comparison, the average value of each of the following parameters was plotted for each site and season: diversity (H'), evenness (J'), species richness (SR), number of species, and abundance (Figure 20).

Average diversity was greatest in the control site and it was most variable in the disposal site where values of 1.4 and 3.8 were obtained at DS11 (winter) and DS08 (summer), respectively. Within each particular area, diversity was generally greater during the summer. Diversity noted at the control site during both seasons was similar to the rather high values reported in the Charleston DMDS (Van Dolah, et al., 1983), while diversity noted in the disposal and "down current" sites was more typical of similar nearshore environments in the Middle Atlantic Bight (Boesch, 1972; Boesch et al., 1977) and further north (Saila et al., 1972).

No obvious differences in evenness (J') were observed among sites; however, a consistent seasonal pattern was detected with average values of J' being greatest during the summer at all areas (Figure 20). Like H', this index was also highly variable among disposal stations, and extreme values were observed at DS08 and DS11, the same stations which exhibited extreme H' values. In the winter, DS11 was heavily dominated (> 81%) by *E. directus* (Appendix 7), which reduced species equitability ($J' = 0.3$), whereas the four dominant species in summer collections at DS08 comprised only 24% of the total number of individuals at that station (Appendix 8).

Species richness (SR) was greatest at control sites, where it exhibited rather marked variation among samples (Figure 20). The highest value was observed at CS10 during winter (23.9), while the lowest value occurred at DC03 during that season (4.6). Control stations also differed from disposal and "down current" sites in that winter samples had higher SR than those taken during summer.

Comparisons of overall faunal abundance at stations within each site indicated that densities were generally highest at the control site during the winter, with a maximum of 3,120 individuals per $0.5\ m^2$ at CS10 (Figure 20). The lowest average density was observed at "down current" stations, with only 78 individuals per $0.5\ m^2$ collected at DC03. Overall faunal abundance was highly variable among the stations (Appendix 11); however, no statistically significant seasonal or spatial patterns of total abundance were detected ($P > 0.2$).

The average number of species per station was highest in the control site during winter (Figure 20), where as many as 193 species were obtained in 5 replicate $0.1\ m^2$ samples at CS10 (Appendices 5 and 11). The fewest species were collected at the "down current" site, where winter collections at DC03 yielded only 21 species in the five grab samples (Appendices 9 and 11). Coincidentally, these were the same stations having the highest and

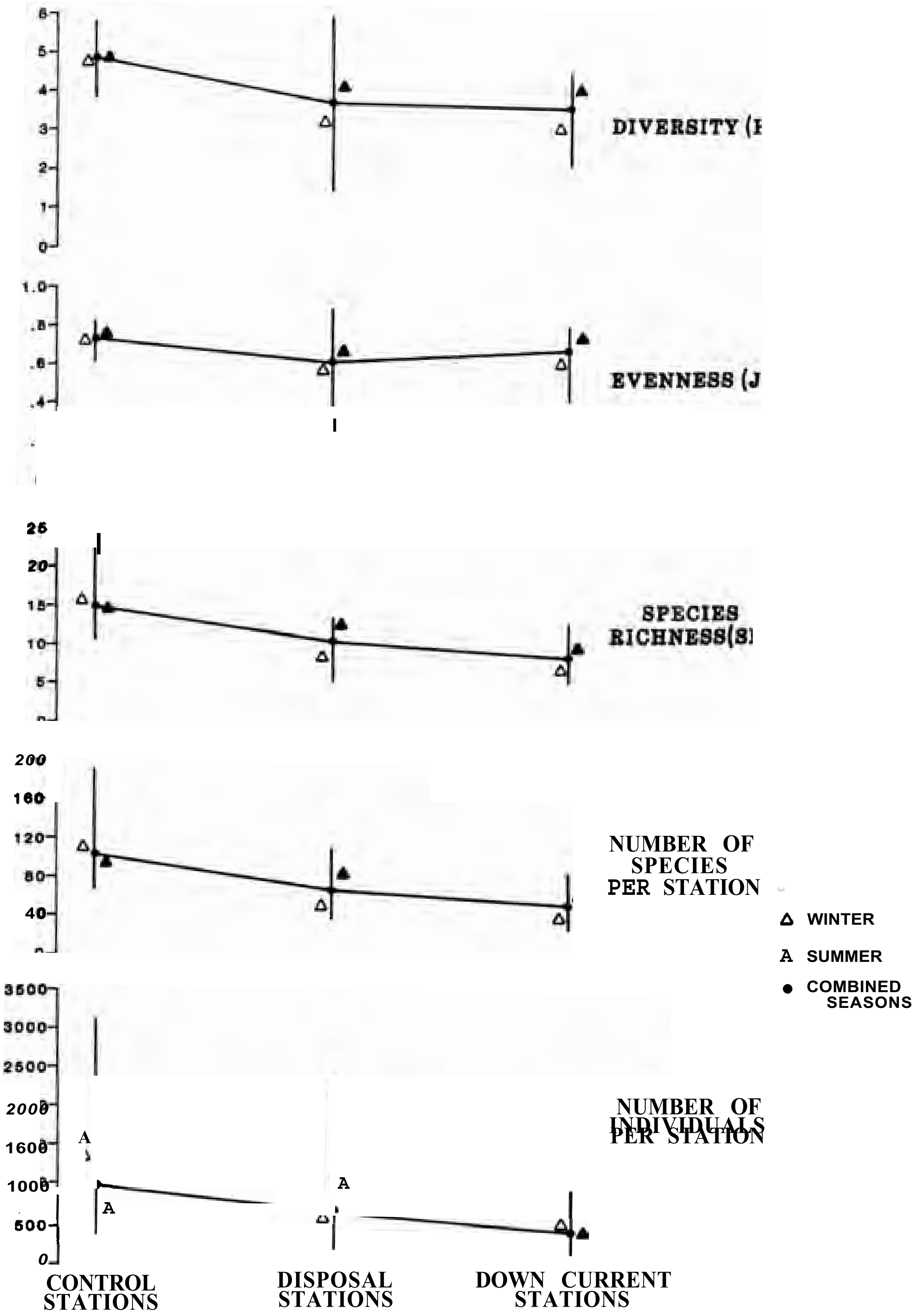


Figure 20. Average values of several community structure parameters at control, disposal, and "down current" sites. The vertical bars indicate' the range of values for each site.

lowest overall faunal densities, respectively. The difference in mean number of species between CS and DC stations was significant during the winter period ($P < 0.02$), but by summer the difference between areas was no longer significant ($P > 0.05$).

The relatively high number of species, faunal density, and diversity of the benthic community observed during winter at the control stations (Figure 20) may be related to differences between sediments in that area and those of the disposal and "down current" areas. Qualitative observations during the winter sampling period indicated the presence of finer sediments in samples from all five control stations. Similar sediments were observed at only one other station in the disposal and "down current" sites during that season. In summer, however, measurements of sediment texture indicated no significant differences in the proportion of fine-grained (silt and clay) sediments among control, disposal and "down current" sites (Table 6). During this period, no obvious differences were noted between control stations and the others based on species richness, diversity and overall abundance (Figure 20). It is unlikely that the distribution of these finer sediments during the winter is related to previous disposal practices. Naturally occurring sediment transport is extensive throughout the study area (Figure 2), and the finer sediments in the control site during winter were probably a result of such processes.

Normal cluster analysis produced five groups of stations with relatively high internal similarity (Figure 21). Some seasonality in community structure was apparent from the arrangement of entities within the dendrogram, since all but one group consisted predominantly of collections from one season or the other. Station groups 2 and 3, for example, were comprised exclusively of summer samples, while groups 4 and 5 were primarily winter collections. Group 1 was an equal mixture of samples from both seasons.

All sampling sites had three stations which were sampled during both seasons (CS02, 09, 13; DS03, 06, 13; DC01, 02, 03). Seven of those stations had winter and summer collections located in different station groups (Figure 21). The remaining two were control stations, CS09 and CS13, indicating smaller seasonal differences in community structure at this site than elsewhere. In fact, group 1, which was equally represented by samples from both seasons, contained nearly all of the CS samples, with the only exceptions being CS02 and CS05 summer samples.

The location of sampling sites belonging to each of the winter station groups further illustrates the difference between the control site and other sites (Figure 22). During this season, the control stations were highly dissimilar to the "down current" and disposal stations, with group 1 being most dissimilar to groups 4 and 5 (Figure 21). This distinction between sites was no longer apparent in the summer, when station groups were either broadly distributed throughout the study area, or limited to a single station (Figure 23).

The inverse classification produced seven species groups which were dissimilar to one another in terms of their occurrence and abundance among station groups (Figure 24, Table 16). Nodal diagrams were constructed to illustrate the distribution of species groups among "fixed" site groups (CS, winter and summer; DS, winter and summer; DC, winter and summer) in order to elucidate possible differences between these sites and/or seasons.

Species group A contained a large number of ubiquitous species that included most of the numerically dominant organisms (Tables 15, 16). These species were highly constant at all sites, especially in the control area, and consequently showed only low fidelity to site groups (Figure 24). Several species in this group, including *C. lunulata*, *Amphiodia pulchella*, and *Metharpinia floridana* were restricted to sandy sediments in the Georgetown entrance channel (Hinde et al., 1981), although no such sediment preferences are apparent from their distribution in the present study.

Group B consisted mainly of polychaetes, ophiuroids and mollusks that were highly constant among control stations during the winter. Their constancy at other sites was moderate to very low, and as a result this group was moderately faithful to the control area. This was the only species group that was even moderately site-restricted (Figure 24). Species in group C showed moderate to low constancy and low fidelity among all site groups.

Species in groups D and E showed greater similarity to one another than to any other groups, and the distribution of their component species among site groups was very similar (Figure 24). These species showed seasonal variation in abundance at all sites, with constancy in summer samples being consistently greater than in winter. They were also more constant at control and disposal sites than at "down current" sites, although they were not highly restricted to any area (Figure 24).

Group F contained several of the more abundant species, including *P. tridentata*, *C. martincensis*, *P. vittata* and *A. gosnoldi* (Table 15, 16). All of these species, except *A. gosnoldi*, were greatest in abundance at the disposal site (Figure 19), and this is reflected in the high constancy of this group at that site (Figure 24). High constancy was also observed for this group at the "down current" stations during summer. Fidelity for this group was low at all sites.

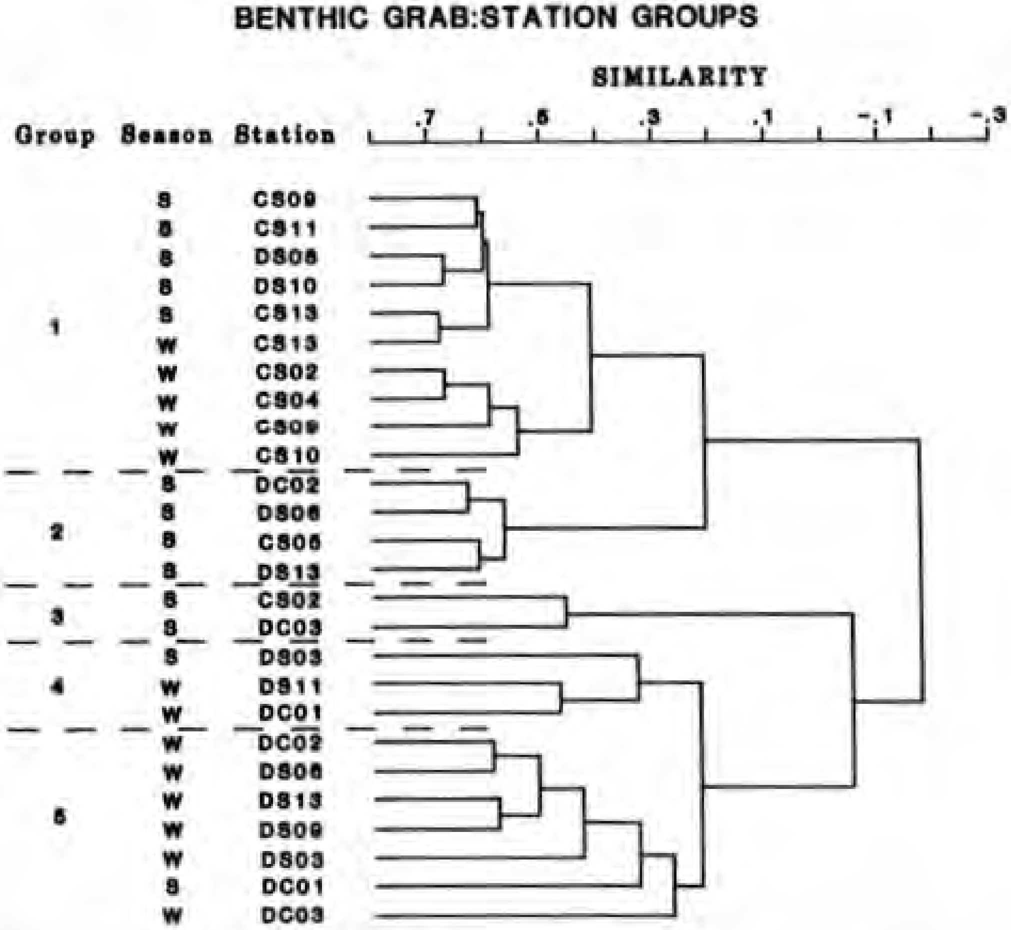


Figure 21. Normal cluster dendrogram of benthic grab samples showing the five station groups formed using flexible sorting.

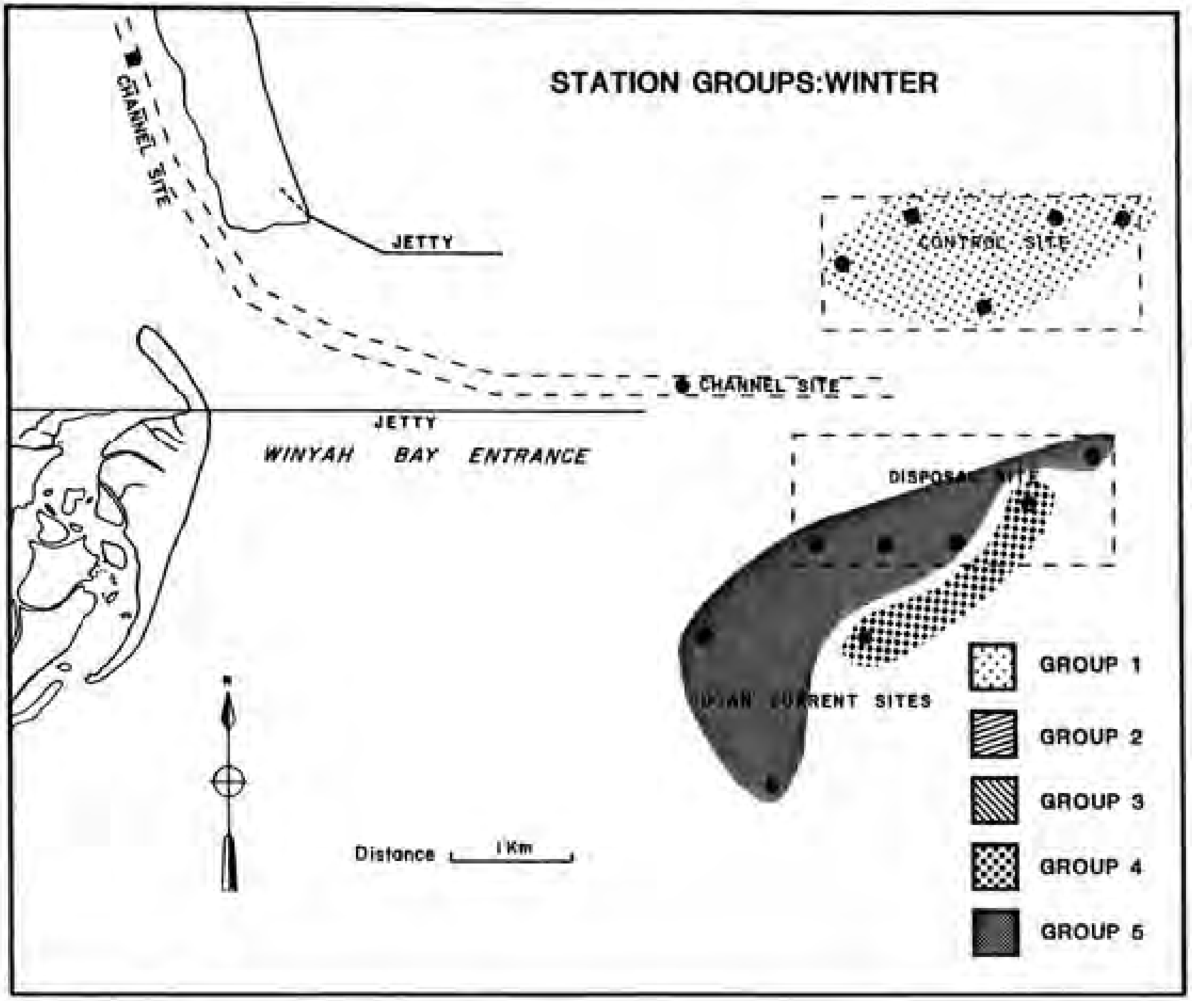


Figure 22. Location of the winter samples among station groups resulting from normal cluster analysis. See Figure 21 for levels of similarity.

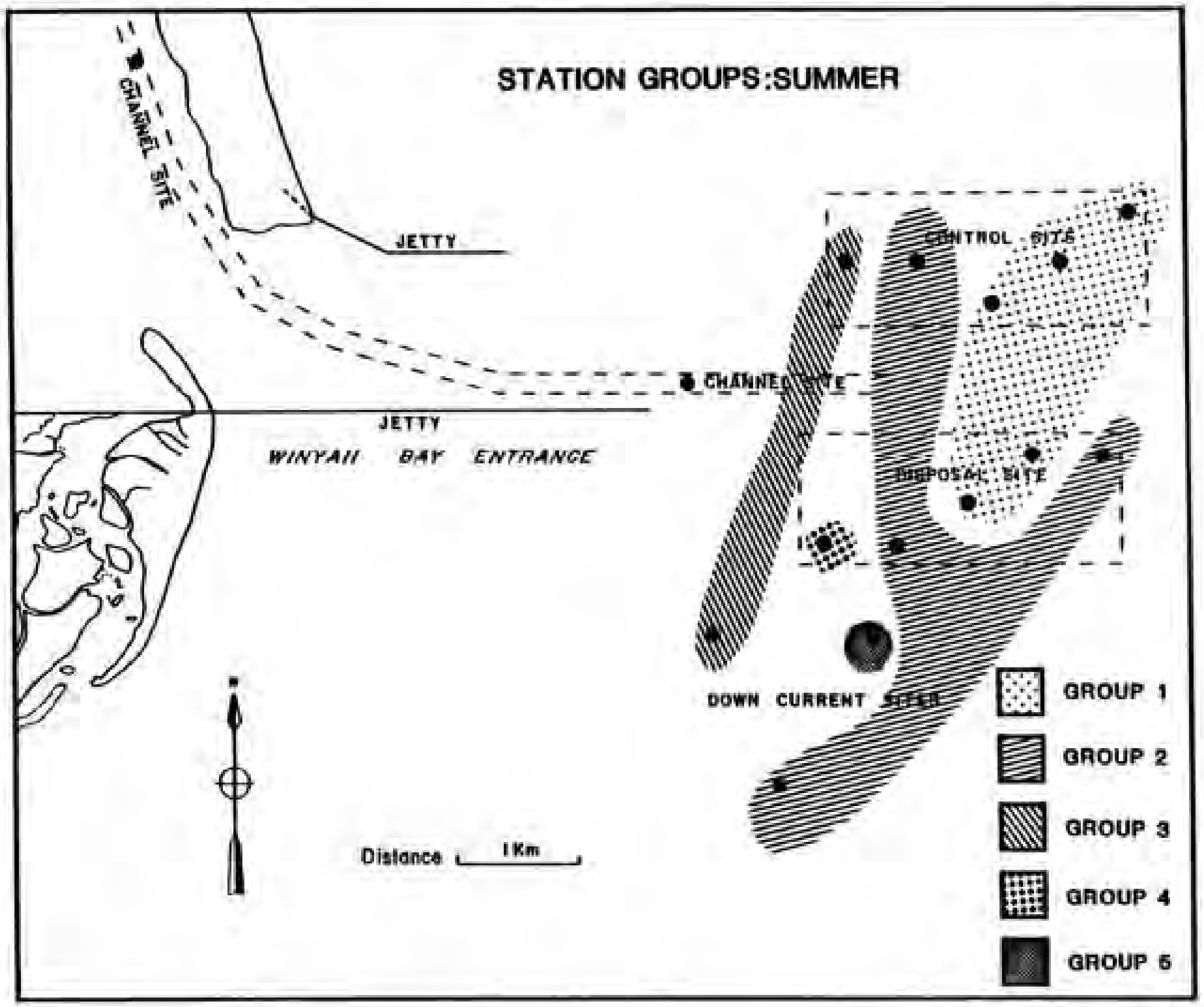


Figure 23. Location of the summer samples among station groups resulting from normal cluster analysis. See Figure 21 for levels of similarity.

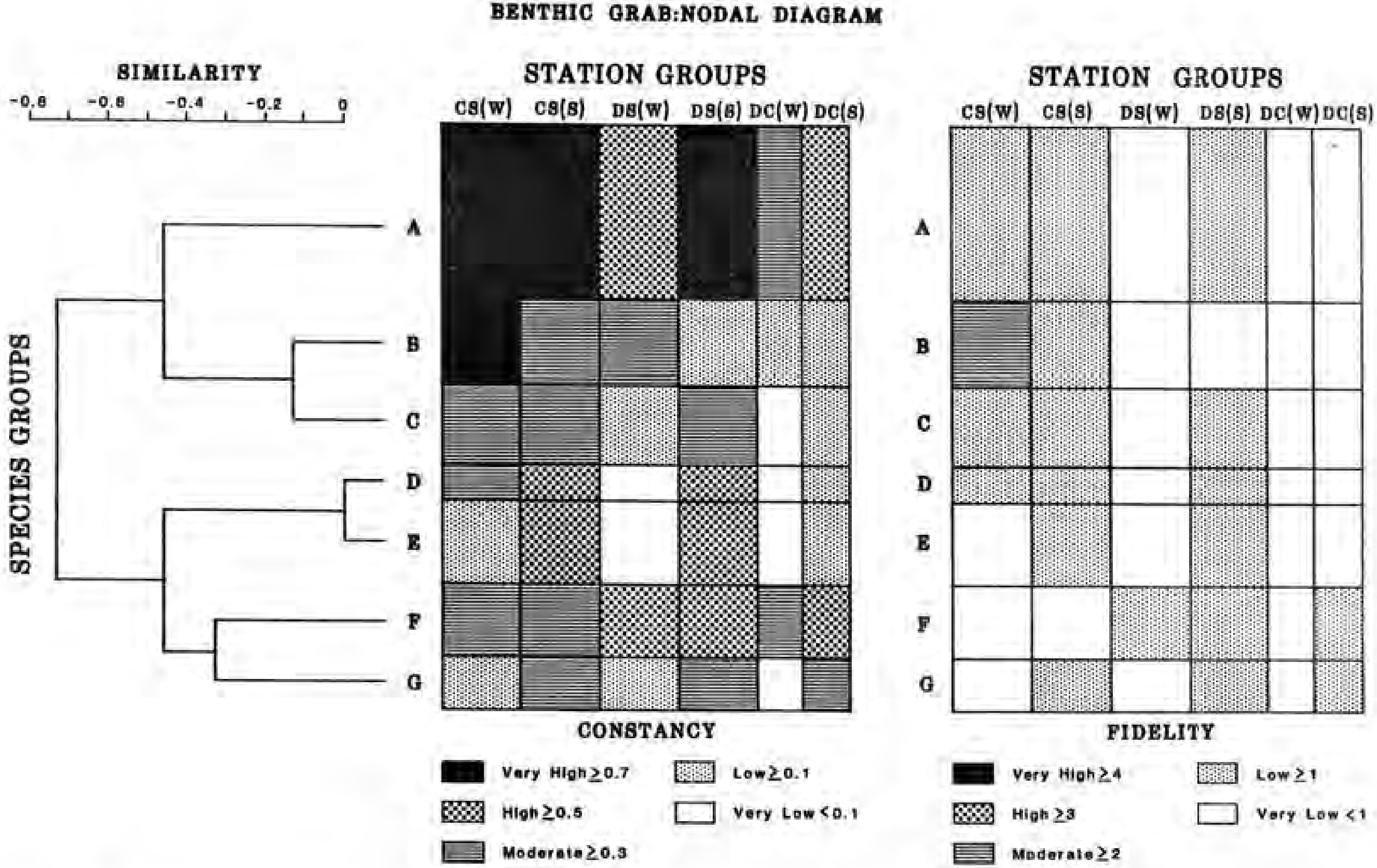


Figure 24. Inverse classification heirarchy of grab collections and nodal diagrams showing constancy and and fidelity of species groups among the sampling sites and seasons.

Table 16. Species groups resulting from inverse cluster analysis of grab samples. (Am = Amphipoda; As = Ascidiacea; Ce = Cephalochordata; Cu = Cumacea; D = Decapoda; E = Echinodermata; I = Isopoda; M = Mollusca; My = Mysidacea; P = Polychaeta; Si = Sipunculida).

Group A

Oligochaeta
Mediomastus californiensis (P)
Nemertinea
Nematoda
Crassinella lunulata (M)
Amphiodia pulchella (E)
Hemipodus roseus (P)
Sabellaria vulgaris (P)
Pagurus hendersoni (D)
Batea catharinensis (Am)
Ensis directus (M)
Polygordiidae A (P)
Actiniaria
Pelecypoda
Maldanidae (P)
Unciola serrata (Am)
Polycirrus eximius (P)
Automate evermanni (D)
Eulalia sanguinea (P)
Pinnixa sp. (D)
Spiophanes bombyx (P)
Nephtys picta (P)
Glycera sp. A (P)
Glycera dibranchiata (P)
Erichthonius brasiliensis (Am)
Exogone dispar (P)
Metharpinia floridana (Am)
Acanthohaustorius millsi (Am)
Oxyurostylis smithi (Cu)

Group B

Crepidula fornicata (M)
Podarke obscura (P)
Ophiuroidea (E)
Bhawania goodei (P)
Hemipholis elongata (E)
Nereis sp. (P)
Nereis succinea (P)
Notocirrus spiniferus (P)
Petricola pholadiformis (M)
Pelecypoda B
Polydora caeca (P)
Cirolana polita (I)
Cirratulidae (P)
Nucula proxima (M)
Elasmopus levis (Am)

Group C

Tharyx annulosus (P)
Brania clavata (P)
Ampelisca vadorum (Am)
Spiophanes sp. A (P)
Diopatra cuprea (P)
Turbellaria
Tharyx marioni (P)
Invertebrata D
Parvulicina multilineata (M)
Pseudeurythoe ambigua (P)
Prionospio fallax (P)
Spio pettiboneae (P)
Ervilia concentrica (M)

Group D

Ancistrosyllis hartmanae (P)
Cirrophorus lyriformis (P)
Goniadides carolinae (P)
Mysidopsis bigelowi (My)
Amaena trilobata (P)
Tiron tropakis (Am)

Group E

Caulleriella kiliariensis (P)
Sigambra bassi (P)
Ampharete americana (P)
Schistomeringos rudolphi (P)
Prionospio cirrifera (P)
Owenia fusiformis (P)
Aspidosiphon albus (Si)
Drilonereis magna (P)
Paraonidae (P)
Leptochela serratorbita (D)
Tiron triocellatus (Am)
Trachypenaeus constrictus (D)
Parapionosyllis sp. A (P)
Promysis atlantica (My)

Group F

Natica pusilla (M)
Travisia parva (P)
Branchiostoma caribaeum (Ce)
Mellita quinquiesperforata (E)
Ancinus depressus (I)
Eudevenopus honduranus (Am)
Glycera oxycephala (P)
Pleuromeris tridentata (M)
Ophelia denticulata (P)
Pyura vittata (As)
Crassinella martinicensis (M)
Aspidosiphon gosnoldi (Si)

Group G

Magelona phyllisae (P)
Magelona rosea (P)
Paraprionospio pinnata (P)
Mulinia lateralis (M)
Pelecypoda
Sigambra tentaculata (P)
Bowmaniella sp. (My)
Bowmaniella brasiliensis (My)
Abra aequalis (M)

Finally, group G consisted of a number of species which had moderate constancy and low fidelity to all areas during the summer; lower values were consistently noted during the winter. Nearly half of the species in this group have been shown to prefer finer sediments with a significant silt or clay content. Hinde et al. (1981) found P. pinnata, Mulinia lateralis, and Sigambra tentaculata to be most common in muddy sediments at Winyah Bay, and Magelona phyllisae and P. pinnata were found in more silty sediments of nearshore waters on the Texas continental shelf (Flint and Rabalais, 1980).

Results of the present study suggest that there have been no long-lasting effects on the benthic infaunal community in the Georgetown DMDS as a result of past disposal activity. This community was characterized by large seasonal and spatial variability in species composition and abundance, which is typical for nearshore environments throughout the South Atlantic Bight (US EPA, 1982). Several noteworthy differences were observed, however, between the infaunal biota of the Georgetown DMDS and the infaunal communities described by the US EPA (1982) off Savannah, Charleston, and Wilmington.

Sediments in the Savannah, Charleston, and Wilmington (SCW) DMDS were characterized primarily as fine to medium sand (US EPA, 1982), while those in the Georgetown site were typically medium to coarse. In addition, greater numbers of species were collected from stations sampled during the present study than from the SCW-DMDS. Other studies off the South Carolina coast, however, indicate that the number of species observed at these Georgetown stations may actually be more typical of similar nearshore environments in the vicinity (Knott et al., 1983b; Van Dolah et al., 1983). Finally, the dominance of the SCW-DMDS by small-bodied deposit-feeders (US EPA, 1982) was not observed in the Georgetown disposal site, where the five most abundant species were the suspension feeders E. directus, C. martinicensis, C. doma, C. lunulata and P. vittata.

Although some of the effects of dredged material disposal, such as increased turbidity, may be transient or localized (Windom, 1976), the impacts of such a disruption would certainly be more severe on a suspension-feeding community such as that found in the Georgetown DMDS, than on a community dominated by deposit feeders. The effects of disposal would be even more obvious if the textural characteristics of disposed sediments were significantly different from the medium-coarse sandy sediments observed throughout this study area. The importance of matching the physical characteristics of the dredged material as closely as possible to the substrate found in the disposal site, in order to minimize potential disruption to the benthic community, has been previously acknowledged (Windom, 1976; Morton, 1977; US EPA, 1982).

Tissue Chemistry

Factors influencing contaminant concentrations in marine organisms include the size and health of the organism, its feeding habits, and its physical location (i.e. within or above the bottom sediments, in the water column, etc.). Depending upon the organism's ability to concentrate a particular contaminant, tissue levels may differ greatly from those in the surrounding environment. For example, oysters examined in the Wando River near Charleston were found to have copper concentrations > 200 μg/g, whereas copper levels in the water were below the detection limit (Mathews et al., 1979). Some typical examples of trace metal concentrations in edible tissue as as follows: 4.0-5.0 ppm arsenic in crustaceans, 0.1-0.3 ppm cadmium in molluscs and crustaceans, 0.3-0.4 ppm chromium in hard clams (Mercenaria mercenaria) and oysters (Crassostrea virginica), 2.0-3.0 ppm copper in hard clams and 30.0-40.0 ppm copper in oysters, 0.5-0.8 ppm lead in molluscs and crustaceans, < 0.3 ppm mercury in crustaceans and < 0.1 ppm mercury in molluscs, 0.2-0.4 ppm nickel for crustaceans, and 10.0-20.0 ppm zinc in hard clams (Hall et al., 1978).

Trace metal concentrations in tissue samples from the three sites sampled during this study were consistently within the limits described above, indicating no unusual accumulation of metals in organisms from this small geographical area. Appendix 12 presents data for all metals analyzed, while Table 3 shows the maxima. Cadmium, chromium, nickel, lead and mercury were all below their particular detection limits and well within the scope of values reported in the survey by Hall et al. (1978). Both arsenic and copper fell within the above limits, with values of 1.67-2.34 μg/g and 6.15-9.65 μg/g, respectively. Although zinc was somewhat higher than the concentrations listed above (50.77-53.61 μg/g), oysters commonly contain zinc ranging from 300-400 ppm (Hall et al., 1978).

No pesticides or PCBs were detected in any of the tissue samples using detection limits of ≥ 50 ppb. Consequently, we assume these contaminants are present in trace quantities only.

RECOMMENDATIONS AND SUGGESTED MONITORING PLAN

The Georgetown DMDS is an easily accessible area for monitoring the effects of dredged material disposal. Based on results obtained from this study we have several recommendations related to environmental and biological assessment in future monitoring efforts.

1) Hydrographic sampling conducted during the present study provided a satisfactory data base for a general evaluation of oceanographic conditions. This sampling effort would not have to be expanded in future assessments.

2) Sampling for trace metals and organic pollutants was also sufficient in terms of the array of pollutants examined. However, the current detection limits for pesticides and PCBs suggested by Pequegnat et al. (1981) may be too high for a proper evaluation of potentially toxic conditions. McKee and Wolf (1963) and Bookhout and Costlow (1976) indicate that trace amounts much lower than the suggested limit of these compounds (≥ 50 ppb) may be lethal to certain organisms. Therefore, we recommend lowering detection limits to at least 1-5 ppb for the PCBs and pesticides tested. Priority should be given to testing pollutant levels in sediments and animal tissue rather than in water since the hydrographic conditions in the study area are so variable.

3) Sedimentological analyses in this study were limited to only one season, but qualitative observations during the other season suggested temporal differences in sediment composition. Therefore, sediment composition and grain-size analyses should be conducted concurrent with every future biological sampling period for a better understanding of faunal distribution patterns. Assessment of contaminants in sediments could be limited to the sampling period(s) immediately following disposal operations. If high levels of pollutants were then detected, an expanded follow-up sampling program should be conducted for those pollutants.

4) Review of topographic data available for the Georgetown DMDS area did not reveal any obvious mounding from previous disposal activities. To better evaluate potential effects of disposal on benthic communities in the DMDS, the Corps of Engineers should require dredge operators to provide precise Loran-C coordinates for all disposal activities. Loran-C receivers are inexpensive and sufficiently accurate to locate potential mound sites. Additionally, we recommend that detailed bathymetric profiles be obtained for the DMDS area immediately after a disposal period, and then again at reasonable intervals for at least one year following disposal. This would permit placement of future monitoring stations in known disposal areas and help in evaluating dispersal of sediments over time.

5) Based on the poor visibility and dangerous current conditions in the study area, we recommend deletion of scuba diving in any future monitoring efforts.

6) The benthic community assessment in the DMDS, control and "down current" areas provided sufficient data on present community composition, as well as information on the temporal and spatial distribution of dominant fauna. Because negative effects of past disposal activities were not noted in this study, future monitoring activities in the Georgetown DMDS area should not need to be intensive, <u>unless</u> (1) a significantly larger amount of sediment is disposed in the area or (2) sediments are disposed in the DMDS which are significantly different from those naturally present. Disposal of larger sediment volumes and/or disposal of finer sediments from Winyah Bay, especially from around Georgetown Harbor, could possibly have more severe and long-term effects on the benthic infauna in and near the DMDS. These effects would most likely be due to direct burial, changes in sediment composition and increased turbidity (Morton, 1977). Thus, intensive biological monitoring would be needed for impact assessment.

7) Any future monitoring program should consider seasonal effects on benthic community composition. If possible, priority should be given to summer and winter periods for best comparisons with data obtained from this study. Infaunal assemblages represent the most important biological component for assessment of impacts from disposal. Epifaunal assemblages are also important, particularly for collection of large animals for tissue analysis, but assessment of impacts on this group is more difficult, since most epifaunal species are relatively motile.

As noted previously, information obtained in this study indicates that past disposal practices in the Georgetown DMDS have not resulted in detectable negative impacts to resources and biota in and near the existing disposal site. Therefore, use of this area for disposal of outer-channel sediments (similar volumes) can be continued, although consideration should be given to avoiding seasons critical to the sturgeon and shrimp fisheries. Alternatively, the site could be relocated further offshore to avoid seasonal restrictions related to these fisheries. The present location of the DMDS may not be suitable if finer sediments were disposed in the area, due to the strong tidal currents present and the location of the DMDS relative to shrimp and sturgeon fisheries and turtle nesting grounds. Our present information base is insufficient to predict the effects of offshore disposal of fine sediments on these resources or on benthic communities.

Summary and Conclusions

1. The Georgetown Ocean Dredged Material Disposal Site was assessed to provide baseline information on present conditions related to the hydrography, bottom sediments and benthic communities. Nearby areas to the north and south, as well as in the entrance channel to Georgetown Harbor, were also assessed for comparison with conditions found in the DMDS.

2. A survey of existing information related to living and non-living resources in the region around Winyah Bay generally supported conclusions and conditions described by the US EPA (1982) for the Savannah, Charleston and Wilmington DMDS. Specific resources which might be affected by disposal in the Georgetown DMDS include the shrimp and Atlantic sturgeon fisheries, and loggerhead turtles (nesting). The sturgeon fishery is the most localized of these three resources, and Winyah Bay is the site of the biggest fishery for this species in the Sea Island region. Other living and non-living resources in the study area will probably not be affected by disposal of predominantly sandy sediments from the outer reaches of the Winyah Bay entrance channel. Disposal of finer sediments from Georgetown Harbor or other areas, however, would possibly have more detrimental effects on the surrounding resources due to increased turbidities and changes in sediment composition. Sufficient studies have not been conducted in this region to fully evaluate the consequences of fine-sediment disposal in offshore sand bottom areas.

3. Sampling was conducted at five sites in the DMDS, five sites in a control area north of the DMDS, three "down current" sites south of the DMDS, and two channel sites. The number of samples varied at each site, but hydrographic, sediment and benthic grab and trawl samples were collected at most stations during summer and winter seasons.

4. Standard hydrographic factors, which included temperature, salinity, dissolved oxygen and turbidity were within the limits normally encountered along the South Carolina coast. Some seasonal and spatial differences were discerned for each factor. High runoff via Winyah Bay resulted in reduced salinities and increased turbidities at some sites. Moderately high turbidities in summer may have been the result of frequent shrimp trawling in the area. Currents in the DMDS appear to be largely tidal, although some evidence of a southerly nearshore current was noted. Trace contaminants in water samples were within or below ranges noted in other areas of the South Atlantic Bight. Many trace metals were below detection limits, as were PCBs and all pesticides tested.

5. Sediment analyses indicated that bottom sediments at most of the sampling sites consisted of medium to coarse sands with very little (< 1%) silt and clay. Stations to the south of the DMDS had consistently finer-grained sediments than those in the DMDS and control areas, but no statistically significant differences were noted among sites. Sediments were low in trace metal and organic contaminant concentrations. Comparisons with other studies indicated that sediments in and near the Georgetown DMDS cannot be considered polluted. No hard bottom areas were found in the entire study area.

6. Benthic epifauna and fishes captured in beam trawl collections were typical of those from sand bottom habitat of South Carolina coastal waters. Community structure was influenced by season, and the number of species was significantly higher in summer. Species assemblages differed noticeably between winter and summer, with several species occurring during only one season. Although the total number of species was lowest in the disposal area, comparison of species composition among the sites indicated that lower diversity resulted from fewer sessile species, mainly bryozoans and cnidarians. This suggests that less hard substrate was available for colonization by sessile organisms in portions of the disposal area, although lesser amounts of hard substrate (i.e. wood, shell) in the DMDS were probably not related to past disposal activities. Tissue analysis of whelks (Busycon carica) collected in and near the DMDS did not reveal any high concentrations of contaminants.

7. The infauna collected in grab samples at the 13 offshore stations were numerically dominated by pelecypods, polychaetes, amphipods and bryozoans. Polychaetes were the most diverse taxon. Of the 357 species collected, many were rare or limited in their distribution. The dominant species, however, were generally ubiquitous throughout the study area and exhibited considerable temporal and spatial variation. No significant differences could be attributed to past disposal activities with respect to species composition or faunal density among the control, disposal and "down current" sites. Unlike the deposit-feeding communities previously described for the SCW-DMDS, the Georgetown DMDS and vicinity were characterized by a seasonally variable, diverse community of suspension-feeding organisms. Numerical classification of the data illustrated some differences in similarity between stations in the control site versus those in the disposal and "down current" areas, particularly during winter. These differences probably were not related to previous disposal practices. Rather, they were most likely due to natural variability in sediment composition. Cluster analysis also indicated that most of the abundant and frequently occurring species were widely distributed throughout the study area.

8. Recommendations for future monitoring at the Georgetown DMDS include lowering the detection limits required for organic contaminants, deleting diver observations, increasing sedimentological and bathymetric surveys, and increasing the intensity and scope of assessments if increased volumes or fine-grained sediments are deposited in the DMDS. The present location of the Georgetown DMDS appears to be satisfactory for continued disposal of outer-channel sediments.

9. An alternative disposal site located farther offshore would reduce potential localized impacts on the shrimp and sturgeon fisheries. Although no evidence was found which indicated that past (limited) disposal in the DMDS has had a significant impact on these fisheries, disposal of finer-grained sediments in the present DMDS might have greater effects.

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Appendices

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Appendix 1. Water current data of sites sampled during the winter and summer, 1983.

WINTER						SUMMER					
Station	Station Depth	Depth	Current Direction	Current Speed (knots)	Tide Phase	Station	Station Depth	Depth	Current Direction	Current Speed (knots)	Tide Phase
DS03	8.0	surface bottom	187° 170°	0.7 0.5	Ebb + 2:00 hrs.	DS03	8.5	surface bottom	012° 015°	0.7 0.4	Slack
DS06	8.0	surface bottom	160° 173°	1.0 0.8	Ebb + 4:30 hrs.	DS06	9.25	surface bottom	290° 110°	0.1 0.5	Ebb + 1:45 hrs.
DS09	9.25	surface bottom	150° 225°	0.9 0.7	Slack	DS08	9.25	surface bottom	160° 225°	0.8 0.4	Ebb + 4:50 hrs.
DS11	9.5	surface bottom	170° 285°	0.3 0.25	Flood + 1:30 hrs.	DS10	9.25	surface bottom	187° 160°	0.7 0.5	Slack
DS13	11.0	surface bottom	322° 305°	0.7 0.6	Flood + 3:05 hrs.	DS13	11.0	surface bottom	020° 010°	0.4 0.4	Slack
CS02	9.5	surface bottom	025° 295°	0.4 0.2	Slack	CS02	9.5	surface bottom	040° 340°	0.5 0.5	Slack
CS04	8.0	surface bottom	050° 155°	0.3 0.1	Ebb + 1:35 hrs.	CS05	7.75	surface bottom	092° 178°	0.2 0.1	Ebb +2:45 hrs.
CS09	9.25	surface bottom	125° 150°	0.5 0.5	Ebb + 3:15 hrs.	CS09	10.0	surface bottom	147° 160°	0.5 0.4	Ebb + 4:40 hrs.
CS10	10.75	surface bottom	145° 155°	0.6 0.5	Ebb + 5:00 hrs.	CS11	10.25	surface bottom	110° 175°	0.4 0.2	Slack
CS13	11.0	surface bottom	125° 225°	0.3 0.1	Slack	CS13	10.5	surface bottom	020° 340°	1.1 0.7	Flood + 4:15 hrs.
DC03	6.5	surface bottom	350° 345°	0.2 0.3	Flood + 4:10 hrs.	DC03	7.5	surface bottom	090° 091°	0.4 0.4	Ebb + 2:35 hrs.
DC02	8.25	surface bottom	235° 190°	0.65 0.3	Slack	DC02	7.3	surface bottom	225° 230°	0.8 0.6	Slack
DC01	7.75	surface bottom	200° 170°	0.5 0.7	Ebb + 1:20 hrs.	DC01	9.5	surface bottom	107° 115°	0.7 0.3	Ebb + 4:00 hrs.

Appendix 2. Hydrographic chemical analysis from Georgetown DMDS area.
(CH - channel, CS - control, DS - disposal, DC - down current)

	CH01	CS05	DS08	DC02	CONTROL	SPIKE
PCBs µg/l	ND	ND	ND	ND	ND	1254 PCB - 100.0% Recovery
α- BHC µg/l	ND	ND	ND	ND	ND	
lindane µg/l	ND	ND	ND	ND	ND	85.2% Recovery
heptachlor µg/l	ND	ND	ND	ND	ND	
B-BHC µg/l	ND	ND	ND	ND	ND	
aldrin µg/l	ND	ND	ND	ND	ND	
heptachlor epoxide µg/l	ND	ND	ND	ND	ND	
P,P^{1} - DDE µg/l	ND	ND	ND	ND	ND	
O,P^{1} - DDD µg/l	ND	ND	ND	ND	ND	
O,P^{1} - DDT µg/l	ND	ND	ND	ND	ND	
chlordane µg/l	ND	ND	ND	ND	ND	
dieldrin µg/l	ND	ND	ND	ND	ND	
endrin µg/l	ND	ND	ND	ND	ND	89.6% Recovery
P,P^{1} - DDD µg/l	ND	ND	ND	ND	ND	
P,P^{1} – DDT µg/l	ND	ND	ND	ND	ND	Methoxychlor - 100.0% Recovery
mirex µg/l	ND	ND	ND	ND	ND	
methoxychlor µg/l	ND	ND	ND	ND	ND	
toxaphene µg/l	ND	ND	ND	ND	ND	
Volume of Sample extracted µg/l	3240	3220	2760	3300	3050	
Total resolved Hydrocarbons by GC µg/l	416.63	259.98	ND	170.18	ND	

Appendix 2. (Continued)

	CH01	CS05	DS08	DC02	CONTROL	SPIKE
Total unresolved Hydrocarbons by GC µg/l	ND	ND	ND	ND	ND	
Sum of the n-Alkanes µg/l	229.01	159.64	ND	23.37	ND	
Sum of the even n-Alkanes µg/l	104.22	115.35	ND	9.62	ND	
Sum of the odd n-Alkanes µg/l	124.79	44.29	ND	13.75	ND	
Unresolved Hydrocarbons/Resolved Hydrocarbons µg/l	$\frac{\text{ND}}{416.63}$	$\frac{\text{ND}}{259.98}$	ND	$\frac{\text{ND}}{170.18}$	ND	
Pristane + Phytane/ n-Alkanes µg/l	$\frac{\text{ND}}{229.01}$	$\frac{\text{ND}}{159.64}$	ND	$\frac{\text{ND}}{23.37}$	ND	
Pristane/n-C17 µg/l	$\frac{\text{ND}}{14.36}$	$\frac{\text{ND}}{2.40}$	ND	ND	ND	
Pristane/n-C18 µg/l	$\frac{\text{ND}}{2.73}$	$\frac{\text{ND}}{1.47}$	ND	$\frac{\text{ND}}{9.62}$	ND	
Pristane/ Phytane µg/l	ND	ND	ND	ND	ND	
n-Alkanes/Branched Hydrocarbons µg/l	$\frac{229.01}{\text{NA}}$	$\frac{159.64}{\text{NA}}$	ND	$\frac{23.37}{\text{NA}}$	ND	
Oil and Grease mg/l	3.0	3.0	4.0	4.0	5.0	
Odd n-Alkanes/ Even n-Alkanes µg/l	$\frac{124.79}{104.22}$	$\frac{44.29}{115.35}$	ND	$\frac{9.62}{13.75}$	ND	
Cadmium µg/l	0.8	7.1	1.6	3.4	< 0.1	
Arsenic µg/l	78.6	92.8	41.4	32.4	< 2.0	
Chromium µg/l	1.4	5.3	4.7	2.1	3.0	
Nickel µg/l	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Copper µg/l	< 50	< 50	< 50	< 50	< 50	
Lead µg/l	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Mercury µg/l	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	
Zinc µg/l	265	150	172	172	140	

ND = Not Detected; Detection limit is 50 ppb.

Appendix 3. Geochemical analysis of sediments from the Georgetown DMDS area. (CH - channel, CS - control, DS - disposal, DC - down current).

	CH01	CH02	CS02	CS05	CS09	CS11	CS13	DS03	DS06	DS08	DS10	DS13	DC01	DC02	DC03	SPIKE CH01
PCBs µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1254 PCB - 55.7% RECOVERY
α - BHC µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
lindane µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	73% RECOVERY
heptachlor µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
B-BHC µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
aldrin µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
heptachlor epoxide µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
P,P^1-DDE µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
O,P^1-DDD µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
O,P^1-DDT µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Chlordane µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Dieldrin µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Endrin µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	100.0% RECOVERY
P,P^1-DDD µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
P,P^1-DDT µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
														Methoxychlor		100.0% RECOVERY
Wet weight of Sample Extracted µg/g	46.3808	47.9552	48.0755	50.3328	49.7783	52.8452	55.0655	52.0564	55.0394	54.7150	58.9654	45.1802	49.3585	55.7648	44.3987	
Dry weight of Sample Extracted µg/g	36.5017	32.9932	34.1336	40.1152	40.0218	43.2802	43.9423	41.3848	45.7928	42.5136	47.5261	35.9183	34.3548	45.1695	29.2387	
% Dry Weight of Wet Weight µg/g	78.7	68.8	71.0	79.7	80.4	81.9	79.8	79.5	83.2	77.7	80.6	79.5	69.4	81.0	65.9	
Total Resolved Hydrocarbons by GC µg/g	ND	ND	8.95	ND	ND	1.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Total Unresolved Hydrocarbons by GC µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

Appendix 3. (Continued)

	CH01	CH02	CS02	CS05	CS09	CS11	CS13	DS03	DS06	DS08	DS10	DS13	DC01	DC02	DC03	SPIKE CH01
Sum of the n-Alkanes µg/g	ND	ND	2.25	ND	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Sum of the even n-Alkanes µg/g	ND	ND	1.03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Sum of the odd n-Alkanes µg/g	ND	ND	1.22	ND	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Unresolved Hydrocarbons/Resolved Hydrocarbons µg/g	ND	ND	ND/8.95	ND	ND	ND/1.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Pristane + Phytane n-Alkanes µg/g	ND	ND	ND/2.25	ND	ND	ND/0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Odd n-Alkanes/ Even n-Alkanes µg/g	ND	ND	1.22/1.03	ND	ND	0.04/ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Pristane/n-C17 µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Phytane/n-C18 µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Pristane/ Phytane µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
n-Alkanes/Branched Hydrocarbons mg/g	ND	ND	2.25/ND	ND	ND	0.04/ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
T.O.C. %	0.086	0.549	0.529	0.047	0.092	0.318	0.124	0.120	0.075	0.082	0.062	0.057	0.810	0.060	0.577	
C.O.D. mg/kg	2880	66300	78200	1800	2600	6900	3300	2930	1.920	2300	1970	1480	88500	1400	34600	
Nitrate as NO_3 mg/g	57.97	278.57	94.59	15.44	25.39	216.66	533.33	17.55	32.66	19.72	19.23	23.85	156	50.77	392	
Nitrate as NO_2 mg/kg	106.28	10.00	8.04	2.28	0.34	2.5	6.34	0.21	2.47	81.31	3.57	2.70	4.46	3.96	27.45	
Soluble Phosphorus as PO_4 mg/kg	1.20	1.63	0.914	0.678	0.446	0.231	1.01	1.72	1.44	1.16	0.849	1.37	1.20	0.646	0.304	
Total Phosphorus as PO_4 mg/kg	8.43	34.72	15.44	9.00	8.20	14.93	8.11	7.17	11.26	6.76	6.57	5.82	53.13	5.92	27.13	
Oil + Grease mg/kg	<6	687	35	57	206	24	8	<6	<6	32	105	81	507	114	<10	
Total Kjeldahl Nitrogen mg/kg	40	546	266	29	36	105	55	39	20	722	696	807	994	31	399	

Appendix 3. (Continued)

Values as determined by 0.1N HCL extraction.

	CH01	CH02	CS02	CS05	CS09	CS11	CS13	DS03	DS06	DS08	DS10	DS13	DC01	DC02	DC03
Cadmium µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel µg/g	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Copper µg/g	<0.1	0.92	<0.1	<0.1	<0.1	1.69	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron µg/g	1,154	1,764	1,084	665	1,181	1,330	826	763	698	933	799	1,128	1,009	822	1,156
Lead µg/g	<0.5	4.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc µg/g	6.05	9.48	7.22	6.65	6.20	10.13	2.77	2.55	2.66	2.78	3.07	2.72	3.64	2.21	5.35
Values as determined by total digestion.															
Cadmium µg/g	< 0.1	< 0.1	< 0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium µg/g	1.25	14.9	3.72	<0.1	8.50	5.97	1.22	1.27	1.22	1.26	2.46	1.16	1.22	1.25	9.05
Nickel µg/g	< 0.5	9.95	< 0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5.89	<0.5	<0.5	<0.5	<0.5
Copper µg/g	< 0.1	2.49	< 0.1	<0.1	<0.1	<0.1	<0.1	1.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	4.02
Iron µg/g	5,075	15,473	4,777	2,175	7,900	8,308	4,216	4,227	2,696	3,333	3,058	2,180	3,648	3,608	11,558
Lead µg/g	< 0.5	<0.5	< 0.5	<0.5	< 0.5	< 0.5	<0.5	< 0.5	< 0.5	< 0.5	< 0.5	<0.5	<0.5	<0.5	< 0.5
Zinc µg/g	9.60	41.04	13.39	14.17	20.25	22.89	7.64	11.14	5.38	9.64	10.77	6.03	9.40	7.83	23.77
Arsenic µg/g	1.44	1.38	1.44	0.41	1.18	1.44	1.47	0.77	0.36	1.34	1.06	1.36	1.38	1.07	1.36
Mercury µg/g	0.27	0.51	0.34	0.35	0.38	0.11	0.35	0.41	0.08	0.61	0.14	0.22	0.42	0.21	0.55

ND - Not Detected; Detection Limit is 50 ppb.

Appendix 4. Taxa collected by beam trawl at control (CS), disposal (DS), and "down current"(DC) sites during winter (w) and summer (s) 1983.

	CS02	CS04	CS05	CS09	CS10	CS11	CS13	DS03	DS06	DS08	DS09	DS10	DS11	DS13	DC01	DC02	DC03
Phylum Chlorophyta																	
<u>Ulva</u> <u>lactuca</u>			s														
Phylum Phaeophyta																	
<u>Sargassum</u> <u>natans</u>			s							s					s		s
Phylum Rhodophyta																	
<u>Rhodymenia</u> <u>pseudopalmata</u>								w									
Phylum Porifera																	
<u>Endectyon</u> <u>tenax</u>																	w
<u>Haliclona</u> sp.																	w
<u>Homaxinella</u> <u>rudis</u>										s							
<u>Ircinia</u> <u>campana</u>				s													
<u>Tenaciella</u> <u>obliqua</u>																s	s
Phylum Cnidaria																	
Actiniaria A						s											w
Actiniaria B															s		
Actiniaria C							s										
Actiniaria (undet.)					w												
<u>Aglaophenia</u> <u>trifida</u>															s		
<u>Astrangia</u> <u>astreiformis</u>			s		w	s	w,s					s		s	s		
<u>Bougainvillia</u> sp.							s										
<u>Calliactis</u> <u>tricolor</u>	s		s	s		s	s					s			s	s	
<u>Clytia</u> <u>cylindrica</u>			s														
<u>Clytia</u> <u>fragilis</u>						s											
<u>Epizoanthus</u> <u>americanus</u>				w												w	
<u>Eudendrium</u> sp.						s											
<u>Halecium</u> sp.	w,s	w		w	w	s	w	s	w			s	w,s	w,s	w	w	w
<u>Hydractinia</u> <u>echinata</u>	s		s	s											s		
<u>Leptogorgia</u> <u>virgulata</u>																s	
<u>Paranthis</u> <u>rapiformis</u>																	w
<u>Renilla</u> <u>reniformis</u>															s		
Scyphozoa (undet.)									s								
<u>Tamoya</u> <u>haplonema</u>									s								
<u>Telesto</u> <u>fruticulosa</u>					w	s											w
Tubulariidae A			s														
Phylum Ctenophora																	
Ctenophora (undet.)															s		
Phylum Bryozoa																	
<u>Aeverrillia</u> <u>setigera</u>			s														
<u>Alcyonidium</u> <u>hauffi</u>																s	
<u>Anguinella</u> <u>palmata</u>					w												
<u>Antropora</u> <u>leucocypha</u>																w	

Appendix 3. Geochemical analysis of sediments from the Georgetown DMDS area. (CH - channel, CS - control, DS - disposal, DC - down current).

	CH01	CH02	CS02	CS05	CS09	CS11	CS13	DS03	DS06	DS08	DS10	DS13	DC01	DC02	DC03	SPIKE CH01
PCBs µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1254 PCB - 55.7% RECOVERY
α - BHC µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
lindane µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	73% RECOVERY
heptachlor µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
B-BHC µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
aldrin µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
heptachlor epoxide µg/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

Appendix 4. (Continued)

	CS02	CS04	CS05	CS09	CS10	CS11	CS13	DS03	DS06	DS08	DS09	DS10	DS11	DS13	DC01	DC02	DC03
Celleporaria albirostris													w				
Crisia sp.	s																
Electra monostachys		w	s			s						s				w	
Hippaliosina rostrigera			s			s											
Hippoporina contracta			s		w	s											
Hippoporina verrilli		w				s								s		w	
Membranipora arborescens	s		s	s	w	s			s			s			s	w,s	s
Membranipora tenuis	s	w	s	w	w	s	w,s			s		s	w	s	s	w	w
Microporella ciliata							w,s			s		s			s		
Nolella stipata																	w
Parasmittina nitida		w	s	w	w	s	w,s						w	w			
Reptadeonella hastingsae		w	s			s	w,s					s	w				
Reptadeonella sp.					w												
Schizoporella errata						s	s					s		s			w
Schizoporella floridana																w	
Stylopoma informata						s											
Trypostega venusta			s				w,s										
Phylum Mollusca																	
Anadara ovalis																	w
Barnea truncata																	w
Brachidontes exustus			s														
Busycon canaliculata			s		w						w						
Busycon carica			s														w
Calliostoma pulchrum							w										
Chama macerophylla						s								s			
Crepidula fornicata	s		s	s		s	w,s	w				s			s	s	s
Crepidula plana	s		s	s	w	s	s	w				s			s	s	
Ensis directus															s		
Eupleura caudata	s						s										
Lolliguncula brevis	s		s	s					s			s			s		s
Polinices duplicatus							s								s		
Sinum perspectivum															s		
Zirfaea crispata					w												
Phylum Echiurida																	
Echiurida (undet.)						s											
Phylum Arthropoda																	
Acetes americanus						s				s							
Alpheus normanni							w										
Arenaeus cribarius	s								s	s						s	s
Anoplodactylus lentus					w												
Balanus calidus																	w
Balanus trigonus			s														
Balanus venustus	s		s		w	s	s					s		s	s	w,s	s
Callinectes sapidus	w,s			s		s		w	w	s							
Callinectes similis	s		s					s	s	s						s	

Appendix 4. (Continued)

	CS02	CS04	CS05	CS09	CS10	CS11	CS13	DS03	DS06	DS08	DS09	DS10	DS11	DS13	DC01	DC02	DC03
Callinectes sp.															s		s
Cancer irroratus					w		w	w									w
Chelonibia patula										s							
Conopea galeata																s	
Hepatus epheliticus	s		s	s		s			w,s	s					s	s	
Hexapanopeus angustifrons	s					s										s	
Hypoconcha sabulosa						s											
Libinia dubia							w										
Libinia emarginata	w,s				w	s	w	w		s			w		w		w
Libinia sp.													w				
Limulus polyphemus				w									w				
Menippe mercenaria	s			s													
Metoporhaphis calcarata					w												
Nanoplax xanthiformis				s													
Neopanope sayi	s				w		w	w									w
Ovalipes ocellatus			s	w,s		s			w,s	s	w				w,s	w	w,s
Ovalipes stephensoni	w,s	w	s	w,s	w	s	s	w,s	w,s	s	w	s	w	w,s	w,s	w,s	w,s
Pagurus hendersoni		w															
Pagurus longicarpus	w,s		s		w				s	s				w	s	w,s	s
Pagurus pollicaris	s	w	s	s	w	s	w,s		s			s			s	s	s
Penaeus aztecus aztecus	s			s				s		s					s	s	s
Penaeus setiferus				s											s		
Penaeus sp.									s								
Persephona mediterranea						s				s		s					
Pilumnus dasypodus								w									
Pilumnus sayi					w	s											w
Porcellana sayana						s		w									
Portunus gibbesii	w,s		s	w	w	s	w,s	w,s	s	s	w	s	w	w	w,s	w,s	w,s
Portunus spinimanus			s		w	s	s			s	w	s	w		s		w
Sicyonia brevirostris						s											
Squilla empusa	s			s	w	s									s		w
Squilla neglecta															s		
Trachypenaeus constrictus	w,s		s	w			w	w,s	s	s	w		w		s	w,s	w
Upogebia affinis							w										
Xanthidae A		w															
Phylum Echinodermata																	
Arbacia punctulata		w	s		w	s	s										
Asterias forbesii		w	s		w	s	w								s		w
Asteroidea A						s	s										
Astropecten duplicatus			s	s	w	s	s										
Luidia clathrata																	w
Lytechinus variegatus					w	s	s										
Mellita quinquiesperforata	s		s		w	s	s		w,s	s		s			s	s	w,s
Ophiothrix angulata							s										
Ophiuroidea A					w												
Ophiuroidea B					w												
Sclerodactyla briareus										s					w,s		

Appendix 4. (Continued)

	CS02	CS04	CS05	CS09	CS10	CS11	CS13	DS03	DS06	DS08	DS09	DS10	DS11	DS13	DC01	DC02	DC03
Phylum Chordata																	
Subphylum Urochordata																	
Aplidium constellatum					w		s	w									w,s
Aplidium sp.			s						s						w		
Ascidiacea A													w				s
Clavelina picta							s										
Clavelina sp.						s											
Molgula occidentalis																	w
Styela plicata																	w
Subphylum Vertebrata																	
Anchoa mitchilli		w		w											w	w	w,s
Ancylopsetta quadrocellata							s	w				s					
Astroscopus y-graecum																	w
Brevoortia tyrannus	w	w		w	w			w			w		w		w	w	w
Centropristis striata					w	w											
Citharichthys macrops		w				s				s			w			s	
Citharichthys spilopterus	s																
Cynoscion regalis			s	s				s	s	s						s	
Etropus crossotus				w		s	s									w	w
Hypsoblennius hentzi						s											
Larimus fasciatus			s	s						s					s	s	
Leiostomus xanthurus	s	w	s	s	w	s		w,s	s			s	w		w,s	s	
Menticirrhus americanus	s																
Menticirrhus littoralis				s													
Micropogonius undulatus	s		s						s	s					s	s	s
Ophidion marginatum																s	
Paralichthys dentatus																w	
Prionotus carolinus			s			s	s		s	s		s		s	s	s	s
Prionotus scitulus						s											
Raja eglanteria	s					s									s	s	
Rhinoptera bonasus									s	s							
Scopthalmus aquosus			s	s		s		w	s	s			w		w,s	s	w,s
Stellifer lanceolatus				s				w	s	s					s	w,s	
Symphurus plagiusa	s		s	w,s				w		s	w				w,s		w,s
Syngnathus louisianae						s											
Trichiurus lepturus								s									
Trinectes maculatus								s									s
Urophycis regia																w	w

Appendix 5. Overall ranked abundance of macroinvertebrates collected during winter at the control site. Mean density (number per 0.1 m^2) and standard error of the mean at each station is indicated.

CONTROL AREA, WINTER SAMPLES

RANK	SPECIES	CS02		CS04		CS09		CS10		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
1	ENSIS DIRECTUS	64.0	12.1	23.4	6.9	10.8	3.7	40.4	5.4	43.2	10.9
2	CRASSINELLA LUNULATA	7.4	2.4	6.4	3.8	12.4	3.0	17.2	2.3	46.2	17.8
3	BATEA CATHARINENSIS	2.8	1.0	0.4	0.4	4.8	2.8	70.2	20.8	1.2	1.0
4	ERICHTHONIUS BRASILIENSIS	0.4	0.4	.	.	3.6	1.7	67.2	28.1	4.0	1.5
5	POLYGORDIIDAE A	30.2	9.5	2.8	1.2	6.4	1.7	16.4	4.1	5.8	2.0
6	NEMATODA	0.4	0.2	7.8	1.5	13.4	6.4	13.6	3.6	12.8	5.4
7	CRASSINELLA MARTINICENSIS	1.6	0.6	3.4	1.9	.	.	0.4	0.4	36.8	19.1
8	NEMERTINEA	4.4	1.7	3.4	1.5	7.2	1.3	21.4	4.9	3.2	1.3
9	ASPIDOSIPHON GOSNOLDI	.	.	32.6	7.2	.	.	.	.	1.2	0.7
10	EXOGONE DISPAR	.	.	.	.	0.6	0.4	29.4	6.7	0.8	0.4
11	METHARPINIA FLORIDANA	0.8	0.4	1.2	0.4	2.6	0.7	16.4	3.8	6.4	4.5
12	MEDIOMASTUS CALIFORNIENSIS	1.8	0.9	2.8	0.5	1.8	0.6	17.6	7.3	3.2	1.1
13	NEREIS FALSA	.	.	.	.	0.6	0.4	20.4	7.5	.	.
14	AMPHIODIA PULCHELLA	0.6	0.6	8.4	3.4	.	.	10.4	3.6	1.2	0.6
15	OXYUROSTYLIS SMITHI	0.4	0.4	1.0	0.6	0.8	0.6	7.4	2.6	10.4	2.5
15	OLIGOCHAETA	1.8	1.8	2.4	1.7	4.8	2.0	3.8	1.9	7.2	3.7
17	PYURA VITTATA	0.4	0.2	8.2	2.8	0.6	0.4	0.2	0.2	10.2	6.3
18	NEREIS SP.	0.4	0.2	0.4	0.2	0.4	0.2	17.6	5.4	0.2	0.2
19	UNCIOLA SERRATA	3.0	1.4	2.6	0.7	1.2	0.6	7.2	1.6	1.8	1.0
20	PAGURUS HENDERSONI	6.2	4.2	.	.	1.2	1.2	8.0	5.4	.	.
20	ELASMOPUS LEVIS	1.8	1.3	0.2	0.2	2.2	1.6	11.2	3.7	.	.
22	EPIZOANTHUS AMERICANUS	.	.	1.2	0.8	.	.	13.6	4.5	0.2	0.2
23	SABELLARIA VULGARIS	2.0	1.3	4.4	1.3	0.6	0.4	7.4	2.0	0.2	0.2
24	SPIOPHANES BOMBYX	1.6	0.7	0.4	0.2	0.4	0.2	10.6	1.1	0.8	0.6
25	HEMIPHOLIS ELONGATA	0.8	0.6	0.6	0.6	0.4	0.2	11.2	2.4	0.4	0.4
26	CREPIDULA FORNICATA	1.0	0.8	0.8	0.4	2.6	1.9	8.0	2.9	0.2	0.2
26	NEREIS LAMELLOSA	0.2	0.2	.	.	0.2	0.2	12.2	1.7	.	.
28	NEREIS SUCCINEA	2.2	1.5	0.4	0.2	1.6	0.9	7.0	0.9	0.2	0.2
29	INVERTEBRATA D	.	.	0.4	0.4	4.8	1.5	2.2	1.0	2.0	0.9
30	HEMIPODUS ROSEUS	1.2	0.7	3.2	1.5	3.8	0.7	.	.	1.0	0.5
31	PODARKE OBSCURA	0.2	0.2	1.6	1.1	0.4	0.4	6.2	1.8	0.2	0.2
32	BRANIA CLAVATA	.	.	.	.	.	.	7.6	2.3	0.8	0.4
33	ASTYRIS LUNATA	0.2	0.2	.	.	.	.	8.0	4.0	.	.
34	GLYCERA SP. A	1.4	0.5	1.2	0.4	0.6	0.2	3.8	1.0	0.8	0.5
35	OPHIUROIDEA	0.6	0.4	4.0	1.9	0.2	0.2	2.2	1.4	0.4	0.4
36	ACANTHOHAUSTORIUS MILLSI	1.2	0.8	.	.	1.8	1.6	2.2	0.4	2.0	1.1
37	AUTOLYTUS SP.	.	.	.	.	0.2	0.2	6.6	1.9	.	.
38	NEPHTYS PICTA	2.0	0.7	1.4	0.7	1.0	0.4	1.4	0.5	0.6	0.2
39	DIOPATRA CUPREA	0.8	0.5	.	.	0.2	0.2	5.2	1.2	.	.
40	POLYCIRRUS EXIMIUS	.	.	3.4	2.2	.	.	2.2	0.7	0.4	0.2
40	POLYDORA CAECA	2.0	1.0	2.8	1.1	.	.	1.2	0.4	.	.
42	NUCULA PROXIMA	3.0	1.3	1.8	0.7	.	.	.	.	0.4	0.2
43	BHAWANIA GOODEI	.	.	1.8	0.6	0.2	0.2	2.2	1.5	0.8	0.4
43	NOTOCIRRUS SPINIFERUS	.	.	0.2	0.2	1.6	1.6	3.0	1.1	0.2	0.2
45	LEMBOS SMITHI	0.4	0.4	.	.	.	.	4.2	1.5	0.2	0.2
45	EULALIA SANGUINEA	0.2	0.2	1.6	0.8	.	.	2.2	0.7	0.8	0.4
47	PINNIXA SP.	0.6	0.4	1.2	0.6	.	.	2.6	1.2	0.2	0.2
48	PETRICOLA PHOLADIFORMIS	2.6	1.5	1.0	0.4	.	.	0.6	0.4	.	.
48	NEPHTYIDAE	.	.	.	.	.	.	1.2	0.8	3.0	1.6
50	GLYCERA DIBRANCHIATA	0.8	0.4	1.6	0.4	0.8	0.6	0.4	0.2	0.4	0.2
50	PISTA QUADRILOBATA	.	.	.	.	.	.	4.0	1.0	.	.
53	AUTOMATE EVERMANNI	0.6	0.4	0.6	0.4	0.2	0.2	1.0	0.4	1.0	0.4
53	TURBELLARIA	.	.	0.2	0.2	.	.	3.0	0.8	0.2	0.2
53	GONIADIDES CAROLINAE	.	.	.	.	.	.	0.4	0.4	3.0	0.8
56	AMAEANA TRILOBATA	.	.	.	.	0.2	0.2	.	.	3.0	2.5
56	ANCISTROSYLLIS HARTMANAE	.	.	0.2	0.2	0.8	0.4	0.2	0.2	2.0	0.4
56	SPIO PETTIBONEAE	.	.	.	.	0.6	0.4	2.4	0.9	0.2	0.2
56	CIRRATULIDAE	0.6	0.2	0.4	0.2	0.2	0.2	1.4	0.5	0.6	0.4
59	AMPELISCA VADORUM	.	.	.	.	.	.	3.0	0.7	.	.
59	SPIOPHANES SP. A	.	.	.	.	.	.	3.0	1.3	.	.
62	XANTHIDAE	0.4	0.2	.	.	0.8	0.5	1.6	1.0	.	.
62	CIROLANA POLITA	0.6	0.2	1.2	0.4	0.2	0.2	0.2	0.2	0.6	0.6

Appendix 5.   (Continued)

CONTROL AREA, WINTER SAMPLES

RANK	SPECIES	CS02		CS04		CS09		CS10		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
62	PARACAPRELLA TENUIS	.	.	.	.	.	.	2.8	1.6	.	.
62	PELECYPODA A	0.2	0.2	0.2	0.2	.	.	0.6	0.6	1.8	0.7
66	PAGURUS SP.	.	.	0.2	0.2	0.4	0.4	2.0	2.0	.	.
66	ACTINIARIA	0.2	0.2	0.2	0.2	0.8	0.6	1.0	0.5	0.4	0.2
66	MALDANIDAE	.	.	0.2	0.2	0.2	0.2	1.4	1.2	0.8	0.8
69	PARVILUCINA MULTILINEATA	.	.	.	.	0.2	0.2	1.4	0.7	0.8	0.4
69	ARCIDAE A	0.4	0.2	.	.	.	.	1.8	1.0	0.2	0.2
69	SPHAEROSYLLIS ACICULATA	0.2	0.2	1.6	1.4	0.4	0.4	.	.	0.2	0.2
69	OWENIA FUSIFORMIS	.	.	.	.	.	.	2.4	0.5	.	.
74	PAGURUS CAROLINENSIS	2.2	1.3	.	.	.	.	.	.	.	.
74	THARYX MARIONI	.	.	.	.	.	.	2.0	0.4	0.2	0.2
74	THARYX SP.	.	.	0.2	0.2	0.2	0.2	1.8	0.9	.	.
74	ARMANDIA MACULATA	.	.	.	.	.	.	2.2	0.8	.	.
74	THARYX ANNULOSUS	.	.	.	.	.	.	1.4	0.5	0.8	0.2
77	MUSCULUS LATERALIS	0.4	0.4	.	.	.	.	1.6	0.7	.	.
77	CIRROPHORUS LYRIFORMIS	.	.	.	.	.	.	.	.	2.0	0.8
81	HEXAPANOPEUS ANGUSTIFRONS	0.2	0.2	.	.	.	.	1.6	1.0	.	.
81	NEOPANOPE SAYI	.	.	.	.	.	.	1.8	1.2	.	.
81	MELANELLA SP. B	.	.	.	.	.	.	.	.	1.8	0.7
81	SYLLIDAE	.	.	.	.	0.2	0.2	0.6	0.4	1.0	0.6
81	TEREBELLIDAE	0.2	0.2	.	.	.	.	1.0	0.8	0.6	0.4
81	PRIONOSPIO CIRRHIFERA	0.6	0.4	.	.	.	.	1.2	0.6	.	.
87	LUCONACIA INCERTA	.	.	.	.	.	.	1.6	1.1	.	.
87	LEMBOS SP.	0.2	0.2	.	.	0.4	0.2	0.6	0.2	0.4	0.2
87	NATICA PUSILLA	.	.	.	.	.	.	1.0	0.4	0.6	0.4
87	LITHOPHAGA BISULCATA	.	.	1.6	1.1	.	.	.	.	.	.
87	PRIONOSPIO FALLAX	0.2	0.2	.	.	0.4	0.2	1.0	0.3	.	.
87	SPIO SP. A	.	.	.	.	.	.	1.6	1.0	.	.
93	EOBROLGUS SPINOSUS	0.4	0.2	.	.	.	.	1.0	0.5	.	.
93	PARAMETOPELLA CYPRIS	.	.	.	.	.	.	1.4	0.7	.	.
93	TIRON TROPAKIS	.	.	.	.	.	.	.	.	1.4	0.7
93	NUDIBRANCHIA	0.2	0.2	0.8	0.6	0.4	0.4	.	.	.	.
93	PELECYPODA B	0.4	0.4	0.6	0.2	.	.	0.4	0.4	.	.
93	ODONTOSYLLIS FULGURANS	.	.	.	.	.	.	1.4	0.5	.	.
99	CANCER IRRORATUS	.	.	.	.	0.2	0.2	1.0	0.3	.	.
99	UNCIOLA SP.	.	.	0.2	0.2	0.2	0.2	0.4	0.2	0.4	0.2
99	ASPIDOSIPHON ALBUS	.	.	0.8	0.4	.	.	0.4	0.2	.	.
99	MAGELONA PHYLLISAE	0.6	0.6	.	.	0.6	0.2	.	.	.	.
99	PARAONIDAE	.	.	.	.	0.4	0.2	.	.	0.8	0.4
99	SIGAMBRA BASSI	.	.	0.2	0.2	0.6	0.4	0.4	0.4	.	.
106	OSTRACODA	.	.	0.2	0.2	.	.	.	.	0.8	0.4
106	GASTROPODA	.	.	0.2	0.2	.	.	0.6	0.6	0.2	0.2
106	PLEUROMERIS TRIDENTATA	0.4	0.4	.	.	.	.	.	.	0.8	0.4
106	SPHAERODOROPSIS SP. A	.	.	0.4	0.4	0.2	0.2	.	.	0.4	0.2
106	ONUPHIS NEBULOSA	.	.	.	.	0.2	0.2	0.8	0.5	.	.
106	PSEUDEURYTHOE AMBIGUA	.	.	.	.	0.2	0.2	0.6	0.4	0.2	0.2
106	SCOLELEPIS SQUAMATA	0.2	0.2	.	.	0.2	0.2	.	.	0.6	0.4
106	SCHISTOMERINGOS RUDOLPHI	.	.	.	.	0.2	0.2	0.8	0.4	.	.
119	EUCERAMUS PRAELONGUS	.	.	.	.	.	.	0.6	0.8	.	.
119	PINNIXA CYLINDRICA	.	.	.	.	.	.	0.8	0.6	.	.
119	LISTRIELLA BARNARDI	.	.	.	.	.	.	0.2	0.2	0.6	0.6
119	PELECYPODA	.	.	0.4	0.2	.	.	0.2	0.2	0.2	0.2
119	LYONSIA HYALINA	.	.	.	.	.	.	0.2	0.2	0.6	0.4
119	PHOLADIDAE A	.	.	.	.	.	.	0.8	0.6	.	.
119	SIPUNCULIDA	.	.	.	.	.	.	.	.	0.8	0.8
119	OPHELIA DENTICULATA	.	.	0.4	0.2	0.2	0.2	.	.	0.2	0.2
119	PHERUSA EHLERSI	.	.	.	.	.	.	0.8	0.5	.	.
119	SPHAERODORIDAE	.	.	0.8	0.4	.	.	.	.	.	.
119	ANCISTROSYLLIS SP.	0.2	0.2	0.4	0.2	.	.	.	.	0.2	0.2
119	LOIMIA MEDUSA	.	.	.	.	.	.	0.8	0.2	.	.
119	SIGAMBRA TENTACULATA	.	.	0.4	0.2	0.2	0.2	.	.	0.2	0.2
119	SPIONIDAE	.	.	.	.	.	.	0.4	0.4	0.4	0.2

Appendix 5. (Continued)

CONTROL AREA, WINTER SAMPLES

RANK	SPECIES	CS02 MEAN	CS02 ST ERR	CS04 MEAN	CS04 ST ERR	CS09 MEAN	CS09 ST ERR	CS10 MEAN	CS10 ST ERR	CS13 MEAN	CS13 ST ERR
119	HESIONIDAE	0.4	0.2	0.2	0.2	.	.	0.2	0.2	.	.
119	CAULLERIELLA KILLARIENSIS	.	.	0.2	0.2	0.4	0.4	0.2	0.2	.	.
119	SABELLA MICROPHTHALMA	.	.	.	.	.	.	0.8	0.6	.	.
135	LILJEBORGIA SP. A	.	.	.	.	.	.	.	.	0.6	0.4
135	PHOTIS SP.	.	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2
135	PHOTIS PUGNATOR	.	.	.	.	.	.	0.6	0.6	.	.
135	CUMACEA	.	.	0.2	0.2	.	.	.	.	0.4	0.2
135	MELLITA QUINQUESPERFORATA	.	.	.	.	.	.	0.6	0.4	.	.
135	INVERTEBRATA C	.	.	.	.	.	.	0.6	0.4	.	.
135	ERVILIA CONCENTRICA	.	.	.	.	.	.	0.4	0.4	0.2	0.2
135	ABRA AEQUALIS	0.2	0.2	0.4	0.4	.	.	.	.	.	.
135	MELANELLA SP. A	.	.	0.2	0.2	0.4	0.4	.	.	.	.
135	POLYCHAETA	0.2	0.2	0.2	0.2	.	.	0.2	0.2	.	.
135	PISTA CRISTATA	.	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2
135	DRILONEREIS MAGNA	.	.	.	.	0.4	0.2	0.2	0.2	.	.
135	ORBINIIDAE	0.2	0.2	0.2	0.2	.	.	.	.	0.2	0.2
135	CERATOCEPHALE SP. A	.	.	.	.	.	.	0.6	0.2	.	.
135	POLYNOIDAE A	.	.	.	.	.	.	0.6	0.2	.	.
158	BRANCHIOSTOMA CARIBAEUM	0.2	0.2	.	.	0.2	0.2	.	.	.	.
158	HYPOCONCHA ARCUATA	.	.	.	.	.	.	0.4	0.2	.	.
158	PARAHAUSTORIUS LONGIMERUS	.	.	.	.	.	.	0.4	0.4	.	.
158	RUDILEMBOIDES NAGLEI	.	.	.	.	.	.	0.2	0.2	0.2	0.2
158	MYSIDOPSIS BIGELOWI	.	.	.	.	.	.	.	.	0.4	0.4
158	STENOTHOE SP.	.	.	.	.	.	.	0.4	0.4	.	.
158	PARAPLEUSTES AESTUARIUS	.	.	.	.	.	.	0.4	0.4	.	.
158	EUDEVENOPUS HONDURANUS	.	.	.	.	.	.	0.4	0.2	.	.
158	GLOTTIDIA PYRAMIDATA	.	.	.	.	.	.	0.2	0.2	0.2	0.2
158	TELLINA TEXANA	.	.	.	.	.	.	.	.	0.4	0.2
158	PELECYPODA S	.	.	.	.	.	.	0.2	0.2	0.2	0.2
158	MYTILIDAE A	.	.	.	.	.	.	0.4	0.4	.	.
158	ODOSTOMIA SP. A	.	.	.	.	.	.	0.2	0.2	0.2	0.2
158	ECHIURIDA	.	.	0.2	0.2	0.2	0.2	.	.	.	.
158	HYDROIDES UNCINATA	.	.	.	.	.	.	0.4	0.2	.	.
158	PRIONOSPIO SP.	.	.	.	.	.	.	0.2	0.2	0.2	0.2
158	CIRRIFORMIA GRANDIS	.	.	.	.	.	.	0.4	0.4	.	.
158	ORBINIA AMERICANA	.	.	.	.	.	.	0.2	0.2	0.2	0.2
158	NEREIS ACUMINATA	.	.	.	.	.	.	0.4	0.4	.	.
158	SCOLOPLOS RUBRA	.	.	.	.	0.4	0.2	.	.	.	.
158	LUMBRINERIS LATREILLI	.	.	.	.	0.2	0.2	.	.	0.2	0.2
158	ARMANDIA AGILIS	.	.	.	.	.	.	0.4	0.4	.	.
158	ARICIDEA SUECICA	.	.	.	.	.	.	0.2	0.2	0.2	0.2
158	LUMBRINERIS TENUIS	.	.	.	.	.	.	.	.	0.4	0.2
158	POLYDORA WEBSTERI	0.4	0.4	.	.	.	.	.	.	.	.
158	HAPLOSCOLOPLOS FRAGILIS	.	.	.	.	.	.	0.2	0.2	0.2	0.2
158	CAPITELLIDAE	0.2	0.2	.	.	.	.	0.2	0.2	.	.
158	NEREIDAE	0.2	0.2	.	.	0.2	0.2	.	.	.	.
158	HESIONIDAE A	.	.	.	.	.	.	0.4	0.2	.	.
158	SABELLIDAE	.	.	.	.	.	.	0.4	0.4	.	.
158	POLYDORA SP. B	0.2	0.2	0.2	0.2	.	.	.	.	.	.
158	CHAETOPTERIDAE	0.2	0.2	.	.	.	.	0.2	0.2	.	.
222	PAGURUS LONGICARPUS	.	.	.	.	0.2	0.2	.	.	.	.
222	OVALIPES STEPHENSONI	.	.	.	.	.	.	0.2	0.2	.	.
222	PORTUNUS GIBBESII	.	.	.	.	.	.	.	.	0.2	0.2
222	NANOPLAX XANTHIFORMIS	.	.	.	.	.	.	0.2	0.2	.	.
222	DISSODACTYLUS MELLITAE	.	.	.	.	.	.	0.2	0.2	.	.
222	MICROPHRYS BICORNUTUS	.	.	.	.	.	.	0.2	0.2	.	.
222	HETEROCRYPTA GRANULATA	.	.	.	.	.	.	0.2	0.2	.	.
222	PAGURIDEA	.	.	.	.	.	.	.	.	0.2	0.2
222	HIPPOLYTE NICHOLSONI	.	.	.	.	.	.	0.2	0.2	.	.
222	ACANTHOHAUSTORIUS SP.	.	.	.	.	0.2	0.2	.	.	.	.
222	SYNCHELIDIUM AMERICANUM	.	.	.	.	.	.	.	.	0.2	0.2
222	RUDILEMBOIDES SP.	.	.	.	.	.	.	0.2	0.2	.	.

Appendix 3. (Continued)

CONTROL AREA, WINTER SAMPLES

RANK	SPECIES	CS02		CS04		CS09		CS10		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
222	MAERA CAROLINIANA	.	.	0.2	0.2	.	.	.	.	.	.
222	CERAPUS TUBULARIS	.	.	.	.	.	.	0.2	0.2	.	.
222	CYCLASPIS VARIANS	.	.	.	.	.	.	0.2	0.2	.	.
222	COROPHIUM ACHERUSICUM	0.2	0.2	.	.	.	.	.	.	.	.
222	NEOMYSIS AMERICANA	0.2	0.2	.	.	.	.	.	.	.	.
222	COROPHIUM SP.	.	.	.	.	.	.	0.2	0.2	.	.
222	ACANTHOHAUSTORIUS SHOEMAKERI	.	.	.	.	0.2	0.2	.	.	.	.
222	CAPRELLA PENANTIS	.	.	.	.	.	.	0.2	0.2	.	.
222	MELITA APPENDICULATA	.	.	.	.	.	.	0.2	0.2	.	.
222	AMPHILOCHIDAE	.	.	.	.	.	.	0.2	0.2	.	.
222	TIRON TRIOCELLATUS	.	.	.	.	.	.	.	.	0.2	0.2
222	AMPHIPODA	.	.	.	.	.	.	0.2	0.2	.	.
222	AMPHIPODA E	.	.	.	.	.	.	0.2	0.2	.	.
222	ANOPLODACTYLUS PETIOLATUS	0.2	0.2	.	.	.	.	.	.	.	.
222	RENILLA RENIFORMIS	.	.	0.2	0.2	.	.	.	.	.	.
222	ASTERIAS FORBESII	.	.	.	.	.	.	0.2	0.2	.	.
222	HEMICHORDATA	.	.	.	.	.	.	0.2	0.2	.	.
222	PHORONIS ARCHITECTA	.	.	.	.	.	.	0.2	0.2	.	.
222	INVERTEBRATA F	.	.	.	.	.	.	0.2	0.2	.	.
222	INVERTEBRATA H	.	.	.	.	.	.	0.2	0.2	.	.
222	NUDIBRANCHIA C	.	.	.	.	.	.	0.2	0.2	.	.
222	OLIVELLA MUTICA	.	.	0.2	0.2	.	.	.	.	.	.
222	CORBULA BARRATTIANA	.	.	.	.	.	.	.	.	0.2	0.2
222	PARVANACHIS OBESA	.	.	.	.	.	.	0.2	0.2	.	.
222	ANOMIA SIMPLEX	.	.	0.2	0.2	.	.	.	.	.	.
222	TELLINA AEQUISTRIATA	.	.	.	.	.	.	0.2	0.2	.	.
222	SEILA ADAMSI	.	.	.	.	.	.	0.2	0.2	.	.
222	PELECYPODA T	.	.	.	.	0.2	0.2	.	.	.	.
222	DORIDELLA BURCHI	.	.	.	.	.	.	0.2	0.2	.	.
222	MODIOLUS MODIOLUS SQUAMOSUS	.	.	.	.	.	.	0.2	0.2	.	.
222	EPITONIUM SP.	0.2	0.2	.	.	.	.	.	.	.	.
222	MITRELLA SP. A	.	.	.	.	.	.	0.2	0.2	.	.
222	ACTEOCINA CANALICULATA	.	.	.	.	.	.	.	.	0.2	0.2
222	TURBONILLA SP. C	.	.	.	.	.	.	0.2	0.2	.	.
222	TEREBRA CONCAVA	.	.	.	.	.	.	.	.	0.2	0.2
222	TURRIDAE B	.	.	.	.	.	.	.	.	0.2	0.2
222	MARGINELLA GUTTATA	.	.	.	.	.	.	0.2	0.2	.	.
222	SCAPHOPODA	.	.	.	.	.	.	0.2	0.2	.	.
222	PARADENTALIUM SP. A	.	.	.	.	.	.	0.2	0.2	.	.
222	COLUS SP. A	.	.	.	.	.	.	0.2	0.2	.	.
222	SIPUNCULIDA A	.	.	.	.	.	.	0.2	0.2	.	.
222	DRILONEREIS SP.	.	.	.	.	0.2	0.2	.	.	.	.
222	SERPULA VERMICULARIS GRANULOSA	.	.	.	.	.	.	0.2	0.2	.	.
222	MAGELONA SP. A	.	.	.	.	0.2	0.2	.	.	.	.
222	NOTOMASTUS AMERICANUS	.	.	.	.	.	.	0.2	0.2	.	.
222	STHENELAIS SP.	.	.	.	.	.	.	0.2	0.2	.	.
222	HARMOTHOE SP.	.	.	0.2	0.2	.	.	.	.	.	.
222	CERATONEREIS SP.	.	.	.	.	.	.	0.2	0.2	.	.
222	HYDROIDES SP. B	.	.	.	.	.	.	0.2	0.2	.	.
222	LUMBRINERIDAE	.	.	.	.	.	.	0.2	0.2	.	.
222	FILOGRANA IMPLEXA	.	.	.	.	.	.	0.2	0.2	.	.
222	PARAPIONOSYLLIS SP.	.	.	.	.	.	.	.	.	0.2	0.2
222	PARAPIONOSYLLIS SP. A	.	.	.	.	0.2	0.2	.	.	.	.
222	ACROCIRRIDAE	.	.	.	.	0.2	0.2	.	.	.	.
222	DORVILLEIDAE	.	.	.	.	.	.	.	.	0.2	0.2
222	CIRRIFORMIA SP.	.	.	.	.	0.2	0.2	.	.	.	.
222	SIGAMBRA SP.	.	.	0.2	0.2	.	.	.	.	.	.
222	STHENELAIS BOA	.	.	.	.	.	.	0.2	0.2	.	.
222	NOTOMASTUS LATERICEUS	.	.	.	.	.	.	.	.	0.2	0.2
222	HYDROIDES PROTULICOLA	.	.	.	.	.	.	0.2	0.2	.	.
222	SPIOCHAETOPTERUS COSTARUM OCULATUS	.	.	.	.	.	.	.	.	0.2	0.2
222	PHYLLODOCE MUCOSA	.	.	.	.	.	.	0.2	0.2	.	.

Appendix 5. (Continued)

CONTROL AREA, WINTER SAMPLES

RANK	SPECIES	CS02		CS04		CS09		CS10		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
222	ONUPHIS EREMITA	.	.	.	.	0.2	0.2	.	.	.	.
222	LEPIDONOTUS SUBLEVIS	.	.	.	.	.	.	0.2	0.2	.	.
222	POECILOCHAETUS SP.	.	.	.	.	.	.	.	.	0.2	0.2
222	SPIO SP.	.	.	.	.	.	.	0.2	0.2	.	.
222	LUMBRINERIS SP.	.	.	.	.	.	.	.	.	0.2	0.2
222	AMPHARETIDAE	.	.	.	.	.	.	0.2	0.2	.	.
222	POLYDORA SP.	.	.	.	.	.	.	0.2	0.2	.	.
222	POLYDORA SP. G	.	.	0.2	0.2	.	.	.	.	.	.
222	POLYDORA SP. H	.	.	.	.	.	.	0.2	0.2	.	.
222	AMPHARETE AMERICANA	.	.	.	.	.	.	0.2	0.2	.	.
222	DORVILLEA SOCIABILIS	.	.	.	.	.	.	0.2	0.2	.	.
222	PHYLLODOCE ARENAE	.	.	.	.	.	.	0.2	0.2	.	.
222	PRIONOSPIO DAYI	.	.	.	.	.	.	0.2	0.2	.	.
222	PRIONOSPIO CRISTATA	0.2	0.2	.	.	.	.	.	.	.	.
222	MAGELONA ROSEA	.	.	.	.	0.2	0.2	.	.	.	.
222	PHYLLODOCIDAE	.	.	.	.	.	.	.	.	0.2	0.2
222	CLYMENELLA TORQUATA	.	.	.	.	.	.	0.2	0.2	.	.
222	POLYNOIDAE	.	.	.	.	.	.	0.2	0.2	.	.
222	CERATONEREIS IRRITABILIS	.	.	.	.	.	.	0.2	0.2	.	.
222	SPIO SETOSA	.	.	0.2	0.2	.	.	.	.	.	.
222	TRAVISIA PARVA	.	.	0.2	0.2	.	.	.	.	.	.
222	SYLLIS HYALINA	.	.	.	.	.	.	0.2	0.2	.	.

Appendix 6. Overall ranked abundance of macroinvertebrates collected during summer at the control site. Mean density (number per 0.1 m^2) and standard error of the mean at each station is indicated.

CONTROL AREA, SUMMER SAMPLES

RANK	SPECIES	CS02		CS05		CS09		CS11		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
1	NEMATODA	0.6	0.4	2.2	1.0	6.4	2.3	4.0	0.9	38.2	8.8
2	MEDIOMASTUS CALIFORNIENSIS	16.6	5.5	0.8	0.8	0.8	0.4	10.2	3.9	15.8	3.3
3	ENSIS DIRECTUS	.	.	0.2	0.2	6.8	2.8	13.0	4.4	23.0	5.2
5	CUPULADRIA DOMA	.	.	0.4	0.4	14.4	3.9	1.4	0.2	17.6	1.8
5	CRASSINELLA LUNULATA	.	.	0.6	0.2	6.4	2.5	11.8	4.3	15.0	5.3
5	PARAPRIONOSPIO PINNATA	33.0	9.5	.	.	.	.	0.6	0.2	0.2	0.2
7	PYURA VITTATA	.	.	28.0	5.7	.	.	1.0	0.6	2.4	2.4
8	CRASSINELLA MARTINICENSIS	0.2	0.2	1.0	0.5	1.4	1.2	0.6	0.2	20.4	4.2
9	OLIGOCHAETA	4.2	1.5	5.6	2.0	1.4	0.5	3.6	2.6	4.4	1.2
10	AMPHIODIA PULCHELLA	.	.	4.6	1.4	0.8	0.4	9.4	2.5	2.6	1.8
11	AMAEANA TRILOBATA	.	.	.	.	0.6	0.6	0.6	0.4	15.2	3.6
12	BATEA CATHARINENSIS	2.8	2.3	0.2	0.2	1.0	1.0	6.0	2.5	4.6	2.8
12	NEMERTINEA	8.4	1.8	2.6	0.9	0.8	0.8	0.8	0.5	2.0	0.9
14	GONIADIDES CAROLINAE	.	.	3.0	1.3	0.6	0.4	2.4	1.1	7.0	1.0
15	ASPIDOSIPHON GOSNOLDI	.	.	4.2	0.9	0.2	0.2	.	.	6.8	1.2
16	ANCISTROSYLLIS HARTMANAE	.	.	0.4	0.2	1.0	0.5	1.2	0.4	8.4	1.3
17	PAGURUS HENDERSONI	0.4	0.4	0.4	0.4	2.0	0.8	6.6	2.4	1.4	0.7
17	POLYGORDIIDAE A	.	.	0.2	0.2	3.2	2.0	1.0	0.6	6.4	1.7
19	EULALIA SANGUINEA	.	.	0.2	0.2	.	.	0.8	0.5	9.2	3.9
20	ERICHTHONIUS BRASILIENSIS	.	.	.	.	0.2	0.2	7.2	3.2	0.6	0.4
21	DISCOPORELLA UMBELLATA	.	.	.	.	.	.	0.6	0.4	6.4	1.4
21	SABELLARIA VULGARIS	0.4	0.2	5.2	1.6	.	.	0.4	0.2	1.0	0.4
23	PINNIXA SP.	0.2	0.2	2.0	0.7	0.2	0.2	0.6	0.6	3.8	1.1
24	CIRROPHORUS LYRIFORMIS	0.2	0.2	1.0	0.5	1.4	0.7	1.6	0.7	1.8	0.6
26	AUTOMATE EVERMANNI	.	.	1.0	0.8	0.8	0.4	1.8	0.6	1.8	1.1
26	CREPIDULA PLANA	5.4	5.4	.	.	.	.	.	.	.	.
26	NUCULA PROXIMA	1.8	0.4	1.6	0.4	0.6	0.2	0.8	0.5	0.6	0.2
26	CREPIDULA FORNICATA	.	.	.	.	.	.	0.2	0.2	5.2	3.5
29	COROPHIUM SP. C	2.0	2.0	.	.	.	.	3.2	2.9	.	.
29	POLYCIRRUS EXIMIUS	.	.	.	.	0.6	0.2	0.6	0.4	4.0	0.9
31	MYSIDOPSIS BIGELOWI	.	.	.	.	0.2	0.2	.	.	4.8	2.8
32	SPIOPHANES BOMBYX	.	.	0.4	0.4	1.4	0.4	1.4	0.7	1.0	0.6
32	OWENIA FUSIFORMIS	0.4	0.2	.	.	0.4	0.2	2.6	0.9	0.8	0.4
34	GLYCERA DIBRANCHIATA	.	.	0.2	0.2	1.0	0.3	0.8	0.4	2.0	1.1
36	METHARPINIA FLORIDANA	.	.	3.0	1.1	.	.	.	.	0.6	0.4
36	TIRON TRIOCELLATUS	.	.	.	.	0.8	0.4	0.4	0.4	2.4	1.0
36	THARYX ANNULOSUS	.	.	.	.	.	.	2.6	2.1	1.0	0.5
40	EUCERAMUS PRAELONGUS	.	.	.	.	.	.	3.4	1.9	.	.
40	PINNIXA RETINENS	.	.	0.2	0.2	.	.	3.2	1.6	.	.
40	PELECYPODA H	0.2	0.2	0.6	0.4	.	.	1.2	0.7	1.4	0.9
40	PARAPIONOSYLLIS SP. A	.	.	.	.	.	.	0.4	0.2	3.0	1.8
40	NEPHTYS PICTA	.	.	0.2	0.2	1.4	0.5	.	.	1.8	0.5
44	CORBULA BARRATTIANA	.	.	0.6	0.4	.	.	2.4	1.6	.	.
44	PELECYPODA U	3.0	1.3	.	.	.	.	.	.	.	.
44	HEMIPODUS ROSEUS	.	.	1.0	0.8	1.0	0.6	0.8	0.4	0.2	0.2
46	ACTINIARIA	.	.	0.4	0.4	0.4	0.2	1.6	0.9	0.4	0.2
46	GLYCERA SP. A	0.6	0.4	0.4	0.4	0.8	0.5	0.2	0.2	0.8	0.6
50	BRACHYURA	.	.	.	.	0.2	0.2	1.6	0.8	0.8	0.4
50	UNCIOLA SERRATA	0.4	0.2	1.0	0.3	0.2	0.2	1.0	0.3	.	.
50	EUDEVENOPUS HONDURANUS	0.2	0.2	.	.	0.8	0.6	0.2	0.2	1.4	0.5
50	PSEUDEURYTHOE AMBIGUA	.	.	.	.	1.4	0.6	0.2	0.2	1.6	0.3
50	PRIONOSPIO CIRRIFERA	.	.	.	.	0.2	0.2	1.2	0.6	1.2	0.7
53	LUMBRINERIS TENUIS	.	.	.	.	.	.	0.2	0.2	2.2	1.0
54	BHAWANIA GOODEI	.	.	.	.	.	.	2.0	0.4	0.6	0.2
55	TRACHYPENAEUS CONSTRICTUS	0.4	0.2	.	.	0.4	0.4	0.6	0.4	0.6	0.6
55	MALDANIDAE	0.2	0.2	0.2	0.2	0.2	0.2	0.8	0.6	0.6	0.2
59	LEPTOCHELA SERRATORBITA	0.2	0.2	.	.	0.4	0.2	0.4	0.2	0.8	0.4
59	AMPELISCA VADORUM	0.4	0.2	.	.	.	.	1.2	0.6	0.2	0.2
59	INVERTEBRATA O	0.2	0.2	.	.	1.0	0.3	.	.	0.6	0.4
59	MAGELONA SP. C	1.8	1.1	.	.	.	.	.	.	.	.
59	DIOPATRA CUPREA	0.6	0.2	.	.	.	.	1.0	0.8	0.2	0.2
59	TRAVISIA PARVA	.	.	1.8	0.2	.	.	.	.	.	.

Appendix 6. (Continued)

CONTROL AREA, SUMMER SAMPLES

RANK	SPECIES	CS02		CS05		CS09		CS11		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
65	CERAPUS TUBULARIS	0.4	0.2	.	.	.	.	1.2	1.2	.	.
65	SPIOPHANES SP. A	0.2	0.2	.	.	.	.	1.2	0.2	0.2	0.2
65	GLYCINDE SOLITARIA	1.6	0.4	.	.	.	.	.	.	.	.
65	NEREIS SP.	.	.	.	.	.	.	0.8	0.6	0.8	0.8
65	SCHISTOMERINGOS RUDOLPHI	.	.	0.2	0.2	0.4	0.2	0.6	0.4	0.4	0.4
71	LATREUTES PARVULUS	.	.	.	.	.	.	1.0	0.3	0.4	0.4
71	NEOPANOPE SAYI	0.4	0.4	0.2	0.2	.	.	0.6	0.4	0.2	0.2
71	OXYUROSTYLIS SMITHI	.	.	0.4	0.2	0.4	0.4	0.4	0.2	0.2	0.2
71	MULINIA LATERALIS	1.4	0.5	.	.	.	.	.	.	.	.
71	MAGELONA SP.	1.2	0.5	.	.	.	.	.	.	0.2	0.2
71	SIGAMBRA TENTACULATA	1.0	0.5	.	.	.	.	0.4	0.4	.	.
71	CIRRATULIDAE	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4
79	ACETES AMERICANUS	.	.	.	.	1.2	1.0	.	.	.	.
79	PROMYSIS ATLANTICA	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4
79	LISTRIELLA BARNARDI	.	.	.	.	.	.	.	.	1.2	0.4
79	TIRON TROPAKIS	.	.	.	.	.	.	.	.	1.2	0.2
79	ASTYRIS LUNATA	.	.	.	.	.	.	1.0	0.5	0.2	0.2
79	PELECYPODA B	.	.	.	.	0.2	0.2	.	.	1.0	0.8
79	PELECYPODA S	.	.	.	.	0.2	0.2	1.0	0.6	.	.
79	ONUPHIDAE	0.2	0.2	.	.	0.2	0.2	.	.	0.8	0.2
79	CISTENIDES GOULDII	.	.	.	.	.	.	0.8	0.4	0.4	0.2
79	EXOGONE DISPAR	.	.	.	.	0.2	0.2	.	.	1.0	0.5
89	SQUILLA EMPUSA	0.8	0.4	.	.	.	.	0.2	0.2	.	.
89	HUMMARIELLA SP.	0.2	0.2	0.6	0.4	.	.	.	.	0.2	0.2
89	SYNAPTIDAE A	.	.	0.4	0.2	.	.	.	.	0.6	0.6
89	ASPIDOSIPHON ALBUS	.	.	.	.	0.6	0.6	0.2	0.2	0.2	0.2
89	PRIONOSPIO FALLAX	.	.	0.2	0.2	0.2	0.2	0.4	0.2	0.2	0.2
89	SPIONIDAE	0.6	0.2	.	.	.	.	0.4	0.2	.	.
89	PARAONIDAE	.	.	.	.	0.4	0.2	0.2	0.2	0.4	0.2
89	BRANIA CLAVATA	.	.	.	.	.	.	0.2	0.2	0.8	0.5
89	NOTOCIRRUS SPINIFERUS	.	.	.	.	0.2	0.2	0.6	0.4	0.2	0.2
101	ELASMOPUS LEVIS	.	.	.	.	.	.	0.6	0.6	0.2	0.2
101	COROPHIUM SP.	0.4	0.4	.	.	0.2	0.2	.	.	0.2	0.2
101	ATYLUS SP.	0.2	0.2	0.4	0.2	0.2	0.2	.	.	.	.
101	PARVILUCINA MULTILINEATA	.	.	.	.	0.2	0.2	.	.	0.6	0.4
101	MACTRA FRAGILIS	.	.	0.2	0.2	.	.	.	.	0.6	0.4
101	ABRA AEQUALIS	0.2	0.2	.	.	0.6	0.4	.	.	.	.
101	PLEUROMERIS TRIDENTATA	.	.	0.2	0.2	.	.	.	.	0.6	0.4
101	SIPUNCULIDA	.	.	.	.	0.2	0.2	0.4	0.2	0.2	0.2
101	PRIONOSPIO SP.	.	.	.	.	.	.	0.6	0.6	0.2	0.2
101	GLYCERA SP. B	.	.	0.8	0.5	.	.	.	.	.	.
101	SPIOCHAETOPTERUS COSTARUM OCULATUS	0.4	0.4	.	.	0.2	0.2	0.2	0.2	.	.
101	DRILONEREIS MAGNA	.	.	.	.	0.4	0.2	.	.	0.4	0.2
101	MAGELONA PHYLLISAE	0.2	0.2	.	.	0.6	0.4	.	.	.	.
101	CAULLERIELLA KILLARIENSIS	0.2	0.2	.	.	.	.	0.4	0.2	0.2	0.2
101	AMPHARETE AMERICANA	.	.	.	.	.	.	0.4	0.2	0.4	0.2
117	DISSODACTYLUS MELLITAE	.	.	0.4	0.4	.	.	0.2	0.2	.	.
117	UPOGEBIA SP.	.	.	.	.	.	.	0.6	0.4	.	.
117	XANTHIDAE	.	.	.	.	.	.	0.4	0.4	0.2	0.2
117	CIROLANA POLITA	.	.	0.6	0.4	.	.	.	.	.	.
117	ANCINUS DEPRESSUS	0.6	0.4	.	.	.	.	.	.	.	.
117	BOWMANIELLA BRASILIENSIS	0.4	0.2	0.2	0.2	.	.	.	.	.	.
117	ERVILIA CONCENTRICA	.	.	.	.	0.6	0.4	.	.	.	.
117	PARVANACHIS OBESA	.	.	.	.	.	.	0.6	0.4	.	.
117	PELECYPODA	0.4	0.4	.	.	.	.	.	.	0.2	0.2
117	MELANELLA SP. A	.	.	0.2	0.2	.	.	0.4	0.4	.	.
117	MAGELONA SP. B	.	.	.	.	.	.	0.2	0.2	0.4	0.4
117	ANCISTROSYLLIS SP.	0.2	0.2	.	.	.	.	.	.	0.4	0.4
117	BOGUEA ENIGMATICA	.	.	.	.	.	.	.	.	0.6	0.6
117	ONUPHIS NEBULOSA	.	.	.	.	.	.	0.6	0.4	.	.
117	NEPHTYS INCISA	.	.	0.2	0.2	0.2	0.2	.	.	0.2	0.2
117	POLYDORA SP.	.	.	.	.	.	.	0.4	0.4	0.2	0.2

Appendix 6. (Continued)

CONTROL AREA, SUMMER SAMPLES

RANK	SPECIES	CS02		CS05		CS09		CS11		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
117	PHYLLODOCIDAE	0.2	0.2	.	.	.	.	0.2	0.2	0.2	0.2
117	POLYNOIDAE	.	.	.	.	.	.	0.6	0.2	.	.
142	OSACHILA TUBEROSA	0.2	0.2	.	.	.	.	0.2	0.2	.	.
142	PENAEIDAE	.	.	0.2	0.2	.	.	0.2	0.2	.	.
142	OSTRACODA	.	.	.	.	0.2	0.2	.	.	0.2	0.2
142	ACANTHOHAUSTORIUS MILLSI	.	.	0.4	0.4	.	.	.	.	.	.
142	APANTHURA MAGNIFICA	.	.	.	.	.	.	.	.	0.4	0.2
142	MICROPROTOPUS SP.	.	.	0.4	0.2	.	.	.	.	.	.
142	EPIZOANTHUS AMERICANUS	.	.	.	.	.	.	.	.	0.4	0.4
142	MELLITA QUINQUESPERFORATA	.	.	0.2	0.2	.	.	0.2	0.2	.	.
142	AMPHIOPLUS SP. A	.	.	.	.	.	.	0.4	0.2	.	.
142	HEMICHORDATA A	0.2	0.2	.	.	.	.	0.2	0.2	.	.
142	INVERTEBRATA G	.	.	.	.	0.2	0.2	0.2	0.2	.	.
142	TELLINA TEXANA	.	.	.	.	.	.	.	.	0.4	0.2
142	SPISULA SOLIDISSIMA	.	.	0.4	0.2	.	.	.	.	.	.
142	TURBONILLA SP. B	.	.	.	.	.	.	.	.	0.4	0.2
142	TURBONILLA SP. C	.	.	.	.	.	.	.	.	0.4	0.2
142	MELANELLA SP.	.	.	.	.	.	.	0.4	0.4	.	.
142	EPISCYNIA MULTICARINATA	.	.	.	.	.	.	0.4	0.4	.	.
142	OPHELIA DENTICULATA	.	.	0.4	0.4	.	.	.	.	.	.
142	POLYDORA TETRABRANCHIA	0.2	0.2	.	.	.	.	.	.	0.2	0.2
142	PARAPIONOSYLLIS SP.	.	.	.	.	.	.	.	.	0.4	0.4
142	DORVILLEIDAE	.	.	.	.	.	.	.	.	0.4	0.4
142	GLYCERA AMERICANA	0.4	0.2	.	.	.	.	.	.	.	.
142	ORBINIA AMERICANA	.	.	0.4	0.4	.	.	.	.	.	.
142	NEREIS LAMELLOSA	.	.	0.2	0.2	.	.	0.2	0.2	.	.
142	ARMANDIA MACULATA	0.2	0.2	.	.	.	.	.	.	0.2	0.2
142	HESIONIDAE B	.	.	0.2	0.2	.	.	.	.	0.2	0.2
142	AMPHARETIDAE	.	.	.	.	.	.	.	.	0.4	0.2
142	PRIONOSPIO CRISTATA	.	.	.	.	.	.	0.4	0.2	.	.
142	MAGELONA ROSEA	0.2	0.2	.	.	.	.	.	.	0.2	0.2
142	SIGAMBRA BASSI	.	.	.	.	.	.	0.4	0.2	.	.
142	SPIO SETOSA	.	.	.	.	.	.	.	.	0.4	0.2
195	BRANCHIOSTOMA CARIBAEUM	.	.	.	.	.	.	.	.	0.2	0.2
195	PERICLIMENES LONGICAUDATUS	.	.	.	.	.	.	0.2	0.2	.	.
195	ALPHEUS FORMOSUS	.	.	.	.	.	.	0.2	0.2	.	.
195	PAGURUS POLLICARIS	0.2	0.2	.	.	.	.	.	.	.	.
195	PORTUNUS SPINIMANUS	.	.	.	.	.	.	0.2	0.2	.	.
195	MICROPHRYS BICORNUTUS	.	.	.	.	.	.	0.2	0.2	.	.
195	HETEROCRYPTA GRANULATA	.	.	.	.	.	.	0.2	0.2	.	.
195	BRACHYURA B	.	.	.	.	.	.	0.2	0.2	.	.
195	PAGURIDAE	0.2	0.2	.	.	.	.	.	.	.	.
195	PROCESSA HEMPHILLI	.	.	.	.	.	.	.	.	0.2	0.2
195	SYNCHELIDIUM AMERICANUM	.	.	.	.	0.2	0.2	.	.	.	.
195	RHEPOXYNIUS EPISTOMUS	.	.	0.2	0.2	.	.	.	.	.	.
195	LYSIANOPSIS ALBA	.	.	.	.	.	.	0.2	0.2	.	.
195	MICROPROTOPUS RANEYI	.	.	.	.	0.2	0.2	.	.	.	.
195	HORULOANTHURA IRPEX	.	.	0.2	0.2	.	.	.	.	.	.
195	BODOTRIIDAE D	.	.	.	.	.	.	.	.	0.2	0.2
195	PHOTIS PUGNATOR	.	.	.	.	.	.	0.2	0.2	.	.
195	LEUCON AMERICANUS	.	.	.	.	.	.	0.2	0.2	.	.
195	UNCIOLA SP.	0.2	0.2	.	.	.	.	.	.	.	.
195	BOWMANIELLA FLORIDANA	0.2	0.2	.	.	.	.	.	.	.	.
195	COROPHIIDAE	.	.	.	.	.	.	0.2	0.2	.	.
195	MICROPROTOPUS SHOEMAKERI	.	.	0.2	0.2	.	.	.	.	.	.
195	AMPHILOCHUS SP. A	.	.	.	.	0.2	0.2	.	.	.	.
195	TURBELLARIA	.	.	.	.	.	.	.	.	0.2	0.2
195	HEMIPHOLIS ELONGATA	.	.	.	.	.	.	.	.	0.2	0.2
195	SCLERODACTYLA BRIAREUS	.	.	.	.	.	.	0.2	0.2	.	.
195	GLOTTIDIA PYRAMIDATA	.	.	.	.	.	.	.	.	0.2	0.2
195	OLIVELLA MUTICA	.	.	.	.	.	.	.	.	0.2	0.2
195	NATICA PUSILLA	.	.	.	.	0.2	0.2	.	.	.	.

Appendix 6. (Continued)

CONTROL AREA, SUMMER SAMPLES

RANK	SPECIES	CS02		CS05		CS09		CS11		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
195	ACTEOCINA CANDEI	.	.	.	.	.	.	.	.	0.2	0.2
195	CYLICHNELLA BIDENTATA	0.2	0.2	.	.	.	.	.	.	.	.
195	VITRINELLIDAE A	.	.	.	.	.	.	0.2	0.2	.	.
195	VITRINELLIDAE B	.	.	.	.	.	.	0.2	0.2	.	.
195	MARGINELLIDAE	.	.	.	.	.	.	0.2	0.2	.	.
195	NASSARIUS TRIVITTATUS	0.2	0.2	.	.	.	.	.	.	.	.
195	PELECYPODA 1	.	.	.	.	.	.	0.2	0.2	.	.
195	LYONSIA HYALINA	.	.	.	.	0.2	0.2	.	.	.	.
195	EPITONIUM SP. A	.	.	.	.	.	.	0.2	0.2	.	.
195	EPITONIUM SP. B	.	.	.	.	.	.	0.2	0.2	.	.
195	CARDIIDAE A	.	.	.	.	0.2	0.2	.	.	.	.
195	AEOLIDIACEA A	.	.	.	.	.	.	0.2	0.2	.	.
195	TROCHIDAE A	.	.	.	.	.	.	.	.	0.2	0.2
195	TEREBRA CONCAVA	.	.	.	.	0.2	0.2	.	.	.	.
195	MELANELLA SP. C	.	.	0.2	0.2	.	.	.	.	.	.
195	MARGINELLA GUTTATA	.	.	.	.	.	.	0.2	0.2	.	.
195	POLYCHAETA	.	.	.	.	.	.	.	.	0.2	0.2
195	PISIONE REMOTA	.	.	.	.	.	.	0.2	0.2	.	.
195	AUTOLYTUS SP.	.	.	.	.	.	.	0.2	0.2	.	.
195	PHERUSA EHLERSI	.	.	.	.	.	.	0.2	0.2	.	.
195	SPHAERODORIDAE	.	.	0.2	0.2	.	.	.	.	.	.
195	POLYGORDIIDAE	0.2	0.2	.	.	.	.	.	.	.	.
195	POLYDORA HARTMANAE	.	.	.	.	.	.	0.2	0.2	.	.
195	NEOAMPHITRITE SP. A	.	.	.	.	.	.	0.2	0.2	.	.
195	PILARGIDAE	.	.	.	.	.	.	.	.	0.2	0.2
195	PROTODORVILLEA KEFERSTEINI	.	.	.	.	.	.	.	.	0.2	0.2
195	STHENELAIS BOA	.	.	.	.	.	.	0.2	0.2	.	.
195	GLYCERA SP.	.	.	.	.	.	.	0.2	0.2	.	.
195	LOIMIA MEDUSA	.	.	.	.	.	.	.	.	0.2	0.2
195	ARICIDEA SUECICA	.	.	.	.	.	.	0.2	0.2	.	.
195	PHYLLODOCE CASTANEA	.	.	.	.	.	.	.	.	0.2	0.2
195	PHYLLODOCE LONGIPES	.	.	.	.	.	.	0.2	0.2	.	.
195	NEREIS SUCCINEA	0.2	0.2	.	.	.	.	.	.	.	.
195	ONUPHIS EREMITA	.	.	0.2	0.2	.	.	.	.	.	.
195	PODARKE OBSCURA	.	.	.	.	.	.	.	.	0.2	0.2
195	MAGELONA PAPILLICORNIS	.	.	.	.	0.2	0.2	.	.	.	.
195	CAPITELLIDAE A	.	.	.	.	.	.	0.2	0.2	.	.
195	NEREIDAE	0.2	0.2	.	.	.	.	.	.	.	.
195	ORBINIIDAE	.	.	.	.	0.2	0.2	.	.	.	.
195	SPIO PETTIBONEAE	.	.	.	.	.	.	.	.	0.2	0.2
195	SYLLIDAE	.	.	.	.	.	.	.	.	0.2	0.2
195	PHYLLODOCE ARENAE	.	.	.	.	0.2	0.2	.	.	.	.
195	POLYDORA CAECA	.	.	.	.	.	.	.	.	0.2	0.2
195	TEREBELLIDAE	.	.	.	.	.	.	.	.	0.2	0.2
195	SYLLIS SPONGICOLA	.	.	0.2	0.2	.	.	.	.	.	.
195	PIONOSYLLIS SP. A	.	.	.	.	.	.	.	.	0.2	0.2

Appendix 7. Overall ranked abundance of macroinvertebrates collected during winter at the disposal site. Mean density (number per 0.1 m^2) and standard error of the mean at each station is indicated.

DISPOSAL AREA, WINTER SAMPLES

RANK	SPECIES	DS03		DS06		DS09		US11		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
1.0	ENSIS DIRECTUS	4.2	2.2	14.2	4.1	31.8	5.5	119.4	31.0	50.8	6.6
2.0	CRASSINELLA MARTINICENSIS	15.0	2.5	26.2	8.1	15.6	6.9	0.2	0.2	41.4	7.7
3.0	PLEUROMERIS TRIDENTATA	3.0	1.5	26.0	6.1	0.8	0.8	.	.	1.4	0.7
4.0	SABELLARIA VULGARIS	0.4	0.2	3.0	1.3	14.4	14.4	.	.	.	.
5.0	PYURA VITTATA	.	.	7.8	3.6	0.8	0.4	.	.	8.2	3.5
6.0	CRASSINELLA LUNULATA	3.0	1.1	0.4	0.2	7.0	1.7	0.2	0.2	4.0	1.6
7.0	ACANTHOHAUSTORIUS MILLSI	.	.	0.8	0.6	3.0	1.0	8.8	1.5	.	.
8.0	NEMATODA	1.0	0.3	0.6	0.6	1.6	0.8	0.2	0.2	5.2	2.3
9.0	POLYGORDIIDAE A	.	.	.	.	7.0	3.9	0.4	0.4	.	.
10.0	ASPIDOSIPHON GOSNOLDI	.	.	.	.	.	.	.	.	7.2	2.6
11.0	NEMERTINEA	1.4	0.5	0.8	0.4	1.8	0.7	0.8	0.6	2.0	1.3
12.0	METHARPINIA FLORIDANA	0.2	0.2	0.2	0.2	2.4	0.9	3.0	0.8	0.4	0.4
13.0	OPHELIA DENTICULATA	1.2	0.2	2.0	1.3	.	.	.	.	2.4	0.6
14.0	EUDEVENOPUS HONDURANUS	.	.	0.8	0.4	.	.	4.2	1.6	0.2	0.2
15.0	TRAVISIA PARVA	.	.	.	.	1.6	0.7	0.4	0.4	2.8	1.2
16.0	PELECYPODA B	1.8	1.1	0.8	0.4	1.2	1.0	.	.	0.2	0.2
17.0	AMPHIODIA PULCHELLA	.	.	1.6	0.5	1.6	0.5	.	.	0.2	0.2
18.5	OXYUROSTYLIS SMITHI	.	.	0.2	0.2	0.2	0.2	1.0	0.3	1.0	0.4
18.5	SPIOPHANES BOMBYX	.	.	.	.	1.0	0.5	0.8	0.2	0.6	0.4
20.5	LEPTOGNATHA CAECA	.	.	.	.	.	.	.	.	2.2	0.6
20.5	MELLITA QUINQUESPERFORATA	.	.	1.0	0.9	0.8	0.4	.	.	0.4	0.4
22.5	ERICHTHONIUS BRASILIENSIS	.	.	0.2	0.2	1.4	0.5	.	.	0.4	0.2
22.5	OLIGOCHAETA	0.2	0.2	0.6	0.6	.	.	0.2	0.2	1.0	0.5
24.5	BATHYPOREIA PARKERI	.	.	.	.	.	.	1.6	0.9	.	.
24.5	POLYCIRRUS EXIMIUS	.	.	0.8	0.8	0.8	0.4	.	.	.	.
28.5	ACANTHOHAUSTORIUS INTERMEDIUS	.	.	.	.	1.4	0.9	.	.	.	.
28.5	NATICA PUSILLA	.	.	.	.	0.2	0.2	0.2	0.2	1.0	0.3
28.5	PETRICOLA PHOLADIFORMIS	0.4	0.2	0.2	0.2	0.6	0.2	.	.	0.2	0.2
28.5	TRAVISIA SP. A	.	.	.	.	1.2	0.7	0.2	0.2	.	.
28.5	NEPHTYS PICTA	.	.	0.2	0.2	0.4	0.4	0.4	0.4	0.4	0.2
28.5	HEMIPODUS ROSEUS	0.2	0.2	1.0	0.6	.	.	.	.	0.2	0.2
32.5	SYNCHELIDIUM AMERICANUM	.	.	.	.	.	.	1.2	0.4	.	.
32.5	ONUPHIS EREMITA	.	.	.	.	1.0	0.5	.	.	0.2	0.2
37.5	BRANCHIOSTOMA CARIBAEUM	.	.	.	.	0.2	0.2	.	.	0.8	0.2
37.5	CYATHURA BURBANCKI	.	.	.	.	.	.	.	.	1.0	0.3
37.5	OPHIUROIDEA	0.8	0.2	.	.	0.2	0.2	.	.	.	.
37.5	ECHINOIDEA A	.	.	.	.	0.6	0.2	.	.	0.4	0.4
37.5	PELECYPODA H	.	.	.	.	.	.	.	.	1.0	0.5
37.5	TELLINA SP.	.	.	0.2	0.2	.	.	.	.	0.8	0.6
37.5	GLYCERA OXYCEPHALA	.	.	0.6	0.4	.	.	0.4	0.2	.	.
37.5	PODARKE OBSCURA	0.2	0.2	0.2	0.2	.	.	.	.	0.6	0.4
45.5	UNCIOLA SERRATA	0.2	0.2	0.2	0.2	0.4	0.2	.	.	.	.
45.5	ACTINIARIA	.	.	.	.	0.6	0.4	.	.	0.2	0.2
45.5	SABELLARIA SP.	.	.	.	.	0.8	0.8	.	.	.	.
45.5	SCOLELEPIS SQUAMATA	.	.	.	.	0.4	0.2	0.2	0.2	0.2	0.2
45.5	SPIO PETTIBONEAE	.	.	.	.	0.2	0.2	0.4	0.2	0.2	0.2
45.5	MALDANIDAE	.	.	0.2	0.2	0.2	0.2	.	.	0.4	0.4
45.5	POLYDORA CAECA	.	.	.	.	0.6	0.6	0.2	0.2	.	.
45.5	LUMBRINERIDES ACUTA	0.2	0.2	.	.	.	.	.	.	0.6	0.6
56.5	OVALIPES SP.	.	.	.	.	0.4	0.2	0.2	0.2	.	.
56.5	APANTHURA MAGNIFICA	.	.	0.2	0.2	.	.	.	.	0.4	0.2
56.5	LEMBOS SP.	.	.	.	.	.	.	.	.	0.6	0.6
56.5	ERVILIA CONCENTRICA	.	.	0.2	0.2	0.2	0.2	.	.	0.2	0.2
56.5	NUCULA PROXIMA	0.6	0.4	.	.	.	.	.	.	.	.
56.5	PELECYPODA E	.	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2
56.5	AMASTIGOS CAPERATUS	.	.	.	.	0.6	0.4	.	.	.	.
56.5	SPHAEROSYLLIS ACICULATA	.	.	.	.	0.6	0.4	.	.	.	.
56.5	LUMBRINERIS LATREILLI	.	.	.	.	0.2	0.2	.	.	0.4	0.4
56.5	NEPHTYS INCISA	.	.	.	.	0.4	0.4	0.2	0.2	.	.
56.5	GLYCERIDAE	.	.	0.2	0.2	.	.	.	.	0.4	0.2
56.5	MAGELONA PAPILLICORNIS	.	.	.	.	.	.	0.6	0.4	.	.
56.5	MEDIOMASTUS CALIFORNIENSIS	.	.	0.4	0.2	.	.	0.2	0.2	.	.

Appendix 7. (Continued)

DISPOSAL AREA, WINTER SAMPLES

RANK	SPECIES	DS03		DS06		DS09		DS11		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
56.5	NOTOCIRRUS SPINIFERUS	0.2	0.2	0.2	0.2	0.2	0.2	.	.	.	.
74.0	AMPELISCA VADORUM	.	.	0.2	0.2	.	.	.	.	0.2	0.2
74.0	OSTRACODA	.	.	.	.	0.2	0.2	0.2	0.2	.	.
74.0	ANCINUS DEPRESSUS	.	.	.	.	0.4	0.4	.	.	.	.
74.0	TIRON TROPAKIS	.	.	.	.	0.2	0.2	.	.	0.2	0.2
74.0	INVERTEBRATA A	0.4	0.4	.	.	.	.	.	.	.	.
74.0	NUDIBRANCHIA	.	.	.	.	0.2	0.2	.	.	0.2	0.2
74.0	PELECYPODA	.	.	.	.	0.2	0.2	.	.	0.2	0.2
74.0	CREPIDULA FORNICATA	.	.	.	.	0.2	0.2	.	.	0.2	0.2
74.0	TURRIDAE C	.	.	.	.	0.2	0.2	0.2	0.2	.	.
74.0	MELANELLA SP. A	0.2	0.2	0.2	0.2	.	.	.	.	.	.
74.0	LIPOPSIS SP. A	.	.	0.2	0.2	.	.	.	.	0.2	0.2
74.0	POLYCHAETA	0.2	0.2	.	.	.	.	.	.	0.2	0.2
74.0	SCOLELEPIS SP.	.	.	0.4	0.4	.	.	.	.	.	.
74.0	GONIADA LITTOREA	.	.	.	.	0.4	0.2	.	.	.	.
74.0	GLYCERIDAE A	.	.	.	.	.	.	.	.	0.4	0.2
74.0	GLYCERA DIBRANCHIATA	0.4	0.2	.	.	.	.	.	.	.	.
74.0	CAPITELLIDAE	0.2	0.2	.	.	0.2	0.2	.	.	.	.
74.0	HESIONIDAE	0.2	0.2	0.2	0.2	.	.	.	.	.	.
74.0	PHYLLODOCIDAE	.	.	.	.	.	.	.	.	0.4	0.4
74.0	NEPHTYIDAE	.	.	.	.	0.4	0.4	.	.	.	.
74.0	SCHISTOMERINGOS CAECA	.	.	.	.	0.4	0.4	.	.	.	.
115.0	PAGURUS LONGICARPUS	.	.	.	.	0.2	0.2	.	.	.	.
115.0	OVALIPES STEPHENSONI	.	.	.	.	.	.	0.2	0.2	.	.
115.0	AUTOMATE EVERMANNI	.	.	.	.	0.2	0.2	.	.	.	.
115.0	PAGURUS SP.	.	.	.	.	0.2	0.2	.	.	.	.
115.0	CIROLANA POLITA	.	.	0.2	0.2	.	.	.	.	.	.
115.0	JERBARNIA AMERICANA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	MAERA CAROLINIANA	0.2	0.2	.	.	.	.	.	.	.	.
115.0	LUCONACIA INCERTA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	PROTOHAUSTORIUS DEICHMANNAE	.	.	.	.	.	.	0.2	0.2	.	.
115.0	BATEA CATHARINENSIS	0.2	0.2	.	.	.	.	.	.	.	.
115.0	CHIRIDOTEA STENOPS	.	.	0.2	0.2	.	.	.	.	.	.
115.0	TANAIDACEA	.	.	.	.	.	.	.	.	0.2	0.2
115.0	UNCIOLA SP.	.	.	.	.	0.2	0.2	.	.	.	.
115.0	ISOPODA	.	.	.	.	.	.	.	.	0.2	0.2
115.0	EPIZOANTHUS AMERICANUS	.	.	.	.	.	.	.	.	0.2	0.2
115.0	HEMIPHOLIS ELONGATA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	HOLOTHUROIDEA	.	.	.	.	.	.	.	.	0.2	0.2
115.0	INVERTEBRATA B	0.2	0.2	.	.	.	.	.	.	.	.
115.0	INVERTEBRATA C	.	.	.	.	0.2	0.2	.	.	.	.
115.0	STRIGILLA MIRABILIS	.	.	.	.	0.2	0.2	.	.	.	.
115.0	PARVILUCINA MULTILINEATA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	PTEROMERIS PERPLANA	.	.	.	.	.	.	.	.	0.2	0.2
115.0	PANDORA TRILINEATA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	POLINICES DUPLICATUS	0.2	0.2	.	.	.	.	.	.	.	.
115.0	ANADARA TRANSVERSA	0.2	0.2	.	.	.	.	.	.	.	.
115.0	DORIDELLA BURCHI	.	.	.	.	0.2	0.2	.	.	.	.
115.0	CHAMA CONGREGATA	.	.	0.2	0.2	.	.	.	.	.	.
115.0	EPITONIUM SP. A	0.2	0.2	.	.	.	.	.	.	.	.
115.0	CORBULA SP.	.	.	.	.	.	.	.	.	0.2	0.2
115.0	ACTEOCINA CANALICULATA	.	.	.	.	.	.	.	.	0.2	0.2
115.0	TURBONILLA SP.	.	.	.	.	.	.	.	.	0.2	0.2
115.0	TEREBRA CONCAVA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	SIPUNCULIDA	.	.	.	.	.	.	.	.	0.2	0.2
115.0	ONUPHIS SP.	.	.	.	.	.	.	.	.	0.2	0.2
115.0	FILOGRANA IMPLEXA	.	.	.	.	.	.	.	.	0.2	0.2
115.0	BRANIA SP.	.	.	.	.	.	.	.	.	0.2	0.2
115.0	DORVILLEIDAE	.	.	.	.	.	.	.	.	0.2	0.2
115.0	ANCISTROSYLLIS SP.	.	.	.	.	0.2	0.2	.	.	.	.
115.0	PROTODORVILLEA KEFERSTEINI	.	.	.	.	.	.	.	.	0.2	0.2
115.0	ONUPHIDAE	.	.	.	.	.	.	.	.	0.2	0.2

Appendix 7. (Continued)

DISPOSAL AREA, WINTER SAMPLES

RANK	SPECIES	DS03		DS06		DS09		DS11		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
115.0	SCOLOPLOS RUBRA	.	.	0.2	0.2	.	.	.	.	.	.
115.0	GLYCERA SP.	.	.	.	.	0.2	0.2	.	.	.	.
115.0	GLYCERA SP. A	.	.	.	.	0.2	0.2	.	.	.	.
115.0	THARYX MARIONI	.	.	.	.	0.2	0.2	.	.	.	.
115.0	ETEONE LACTEA	.	.	.	.	.	.	0.2	0.2	.	.
115.0	PRIONOSPIO FALLAX	.	.	.	.	.	.	.	.	0.2	0.2
115.0	OWENIA FUSIFORMIS	.	.	.	.	0.2	0.2	.	.	.	.
115.0	SIGAMBRA TENTACULATA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	EXOGONE DISPAR	.	.	.	.	.	.	.	.	0.2	0.2
115.0	GONIADA MACULATA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	HAPLOSCOLOPLOS FRAGILIS	.	.	.	.	0.2	0.2	.	.	.	.
115.0	SPIO SP.	.	.	.	.	.	.	.	.	0.2	0.2
115.0	PARAPRIONOSPIO PINNATA	.	.	.	.	0.2	0.2	.	.	.	.
115.0	SCOLELEPIS TEXANA	.	.	.	.	.	.	0.2	0.2	.	.
115.0	SABELLIDAE	.	.	0.2	0.2	.	.	.	.	.	.
115.0	NERINIDES UNIDENTATA	.	.	0.2	0.2	.	.	.	.	.	.
115.0	SYLLIDAE	.	.	.	.	0.2	0.2	.	.	.	.
115.0	TEREBELLIDAE C	0.2	0.2	.	.	.	.	.	.	.	.
115.0	MAGELONA ROSEA	0.2	0.2	.	.	.	.	.	.	.	.
115.0	SIGAMBRA BASSI	.	.	.	.	.	.	0.2	0.2	.	.
115.0	SPIO SETOSA	0.2	0.2	.	.	.	.	.	.	.	.

Appendix 8. Overall ranked abundance of macroinvertebrates collected during summer at the disposal site. Mean density (number per 0.1 m²) and standard error of the mean at each station is indicated.

DISPOSAL AREA, SUMMER SAMPLES

RANK	SPECIES	DS03		DS06		DS08		DS10		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
1	CUPULADRIA DOMA	*	*	12.6	2.7	2.4	0.9	31.2	3.2	177.8	28.8
2	CRASSINELLA MARTINICENSIS	*	*	62.0	7.4	6.2	1.6	11.2	2.4	110.4	17.9
3	PYURA VITTATA	*	*	16.0	4.7	3.2	0.5	20.4	4.0	43.2	5.6
4	SABELLARIA VULGARIS	23.8	11.8	1.2	0.5	2.2	0.6	1.4	0.7	1.4	0.4
5	CRASSINELLA LUNULATA	0.6	0.4	0.6	0.2	6.0	1.6	19.0	4.2	3.2	1.0
6	ASPIDOSIPHON GOSNOLDI	*	*	*	*	0.2	0.2	0.2	0.2	19.4	1.2
7	PLEUROMERIS TRIDENTATA	*	*	17.2	3.5	0.6	0.4	*	*	0.6	0.3
8	OLIGOCHAETA	0.8	0.5	1.4	0.5	5.2	1.1	3.4	1.9	5.8	4.1
9	DISCOPORELLA UMBELLATA	*	*	*	*	0.6	0.2	1.4	0.7	13.4	3.8
10	MEDIOMASTUS CALIFORNIENSIS	1.2	0.4	0.2	0.2	1.2	0.4	7.4	4.5	4.6	1.9
11	ENSIS DIRECTUS	*	*	*	*	3.4	1.0	1.4	1.4	5.6	1.5
12	NEMATODA	0.4	0.2	1.0	0.8	0.2	0.2	4.0	2.1	3.4	2.6
13	NEMERTINEA	1.6	0.6	1.0	0.3	1.0	0.3	2.8	1.6	1.6	0.8
13	POLYGORDIIDAE A	3.0	1.0	*	*	5.0	2.3	*	*	*	*
15	METHARPINIA FLORIDANA	*	*	0.8	0.4	1.8	1.0	3.8	1.6	1.0	0.3
16	GONIADIDES CAROLINAE	*	*	*	*	*	*	3.4	1.0	3.6	2.2
17	CIRROPHORUS LYRIFORMIS	*	*	0.6	0.2	0.6	0.2	4.2	1.9	1.4	0.9
18	ANCISTROSYLLIS HARTMANAE	*	*	0.4	0.2	1.0	0.5	4.0	1.7	1.2	0.7
20	PAGURUS HENDERSONI	*	*	0.6	0.2	3.0	1.3	1.4	0.5	1.2	0.5
20	ACANTHOHAUSTORIUS MILLSI	*	*	4.4	1.3	0.2	0.2	0.4	0.2	1.2	0.4
20	HEMIPODUS ROSEUS	3.4	0.9	0.8	0.5	1.2	0.6	0.4	0.2	0.4	0.2
22	AMPHIODIA PULCHELLA	0.4	0.2	0.6	0.4	1.8	1.0	1.6	0.4	0.6	0.4
23	BOWMANIELLA SP.	0.2	0.2	1.4	0.7	1.6	0.6	1.0	0.4	0.4	0.2
24	BATEA CATHARINENSIS	*	*	0.4	0.4	1.8	0.6	1.6	0.8	0.8	0.6
24	EUDEVENOPUS HONDURANUS	1.8	0.8	0.4	0.2	2.0	1.0	0.4	0.2	*	*
26	ANCINUS DEPRESSUS	0.6	0.2	1.2	0.4	1.4	0.7	*	*	0.4	0.2
26	GLYCERA DIBRANCHIATA	*	*	0.6	0.2	1.6	0.2	1.4	0.5	*	*
30	AUTOMATE EVERMANNI	0.2	0.2	0.4	0.4	1.2	0.6	0.8	0.4	0.4	0.4
30	COROPHIUM SP. C	*	*	*	*	3.0	2.8	*	*	*	*
30	ERVILIA CONCENTRICA	*	*	0.2	0.2	2.0	1.3	0.2	0.2	0.6	0.2
30	ASPIDOSIPHON ALBUS	*	*	*	*	*	*	0.4	0.2	2.6	1.0
30	SPIOPHANES BOMBYX	0.6	0.2	0.6	0.4	0.8	0.6	0.8	0.4	0.2	0.2
34	OXYUROSTYLIS SMITHI	*	*	0.4	0.4	0.2	0.2	1.8	0.7	0.4	0.2
34	CYATHURA BURBANCKI	*	*	*	*	*	*	*	*	2.8	1.1
34	PRIONOSPIO FALLAX	0.2	0.2	0.2	0.2	1.6	0.5	0.6	0.4	0.2	0.2
36	PARAPIONOSYLLIS SP. A	0.4	0.4	0.2	0.2	*	*	1.0	0.6	1.0	0.8
36	NEPHTYS PICTA	0.4	0.2	0.2	0.2	1.2	0.4	0.6	0.4	0.2	0.2
39	TIRON TRIOCELLATUS	0.4	0.2	*	*	0.4	0.2	1.0	0.8	0.6	0.4
39	PSEUDEURYTHOE AMBIGUA	*	*	*	*	2.2	1.5	0.2	0.2	*	*
39	EULALIA SANGUINEA	0.2	0.2	0.2	0.2	0.8	0.4	0.8	0.5	0.4	0.2
41	TRACHYPENAEUS CONSTRICTUS	0.2	0.2	*	*	0.6	0.4	1.0	0.4	0.4	0.4
42	OWENIA FUSIFORMIS	*	*	*	*	*	*	1.6	0.7	0.4	0.4
43	MYSIDOPSIS BIGELOWI	*	*	0.4	0.4	0.6	0.4	0.8	0.8	*	*
43	ABRA AEQUALIS	*	*	1.2	0.6	0.2	0.2	*	*	0.4	0.4
46	PINNIXA RETINENS	*	*	0.4	0.4	0.2	0.2	0.2	0.2	0.8	0.8
46	POLYGORDIIDAE	*	*	*	*	1.6	1.5	*	*	*	*
46	GLYCERA OXYCEPHALA	*	*	0.4	0.4	0.2	0.2	*	*	1.0	0.3
50	BRANCHIOSTOMA CARIBAEUM	*	*	*	*	*	*	*	*	1.4	0.7
50	LEPTOCHELA SERRATORBITA	*	*	1.0	0.5	*	*	0.4	0.4	*	*
50	MELLITA QUINQUESPERFORATA	*	*	0.6	0.4	0.4	0.2	*	*	0.4	0.2
50	PARVILUCINA MULTILINEATA	*	*	*	*	0.6	0.4	0.8	0.4	*	*
50	ORBINIA AMERICANA	*	*	0.2	0.2	1.2	0.7	*	*	*	*
50	SIGAMBRA BASSI	*	*	*	*	0.4	0.2	1.0	0.5	*	*
57	PINNIXA SP.	*	*	*	*	0.2	0.2	0.4	0.4	0.6	0.4
57	LEPTOGNATHA CAECA	*	*	0.6	0.4	*	*	*	*	0.6	0.2
57	BOWMANIELLA BRASILIENSIS	0.2	0.2	0.2	0.2	0.4	0.2	0.4	0.2	*	*
57	TELLINA PROBRINA	*	*	1.0	0.4	*	*	*	*	0.2	0.2
57	PELECYPODA A	*	*	0.4	0.4	0.4	0.2	0.4	0.4	*	*
57	GLYCERA SP. A	0.4	0.4	*	*	0.4	0.2	0.2	0.2	0.2	0.2
57	LUMBRINERIDES ACUTA	*	*	*	*	*	*	*	*	1.2	0.6
65	PROMYSIS ATLANTICA	0.2	0.2	*	*	0.2	0.2	*	*	0.6	0.6
65	ACTINIARIA	*	*	0.4	0.2	0.6	0.6	*	*	*	*

Appendix B. (Continued)

DISPOSAL AREA, SUMMER SAMPLES

RANK	SPECIES	DS03		DS06		DS08		DS10		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
65	SPISULA SOLIDISSIMA	0.4	0.4	0.4	0.2	.	.	.	.	0.2	0.2
65	MACTRA FRAGILIS	.	.	.	.	0.6	0.4	0.4	0.4	.	.
65	PELECYPODA	.	.	.	.	0.4	0.4	0.6	0.6	.	.
65	OPHELIA DENTICULATA	.	.	0.8	0.2	.	.	.	.	0.2	0.2
65	SIGAMBRA TENTACULATA	.	.	0.2	0.2	0.2	0.2	0.6	0.2	.	.
65	PARAPRIONOSPIO PINNATA	0.2	0.2	.	.	0.2	0.2	0.6	0.4	.	.
65	AMPHARETE AMERICANA	.	.	.	.	0.8	0.4	.	.	0.2	0.2
77	PROTOHAUSTORIUS DEICHMANNAE	.	.	0.6	0.2	.	.	.	.	0.2	0.2
77	ERICHTHONIUS BRASILIENSIS	.	.	.	.	0.2	0.2	0.2	0.2	0.4	0.2
77	ACANTHOHAUSTORIUS SHOEMAKERI	.	.	.	.	.	.	.	.	0.8	0.6
77	SPIOPHANES SP. A	.	.	.	.	.	.	0.8	0.6	.	.
77	PILARGIDAE	.	.	.	.	0.2	0.2	0.6	0.4	.	.
77	POLYCIRRUS EXIMIUS	.	.	.	.	0.8	0.4	.	.	.	.
77	SPIOCHAETOPTERUS COSTARUM OCULATUS	.	.	0.2	0.2	0.2	0.2	0.4	0.2	.	.
77	DRILONEREIS MAGNA	.	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
77	PARAONIDAE	.	.	.	.	.	.	0.4	0.2	0.4	0.4
77	SPIO PETTIBONEAE	.	.	.	.	0.2	0.2	0.6	0.4	.	.
77	CAULLERIELLA KILLARIENSIS	0.2	0.2	.	.	0.4	0.2	.	.	0.2	0.2
77	MALDANIDAE	.	.	0.6	0.4	0.2	0.2	.	.	.	.
77	SCHISTOMERINGOS RUDOLPHI	.	.	.	.	.	.	0.4	0.2	0.4	0.2
77	PRIONOSPIO CIRRIFERA	.	.	.	.	.	.	0.4	0.4	0.4	0.4
77	SCHISTOMERINGOS CAECA	.	.	0.4	0.2	0.2	0.2	0.2	0.2	.	.
92	PINNIXA CHAETOPTERANA	.	.	0.6	0.6	.	.	.	.	.	.
92	HETEROCRYPTA GRANULATA	.	.	.	.	.	.	0.4	0.4	0.2	0.2
92	CIROLANA POLITA	.	.	.	.	.	.	.	.	0.6	0.2
92	UNCIOLA SERRATA	.	.	.	.	0.6	0.4	.	.	.	.
92	TIRON TROPAKIS	.	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2
92	HEMICHORDATA A	.	.	.	.	0.6	0.4	.	.	.	.
92	INVERTEBRATA D	.	.	.	.	0.4	0.4	0.2	0.2	.	.
92	CORBULA BARRATTIANA	.	.	0.4	0.2	.	.	.	.	0.2	0.2
92	POLYCHAETA A	.	.	0.6	0.2	.	.	.	.	.	.
92	ONUPHIS SP.	.	.	0.2	0.2	.	.	.	.	0.4	0.2
92	THARYX MARIONI	.	.	0.4	0.2	.	.	.	.	0.2	0.2
92	ARICIDEA SUECICA	.	.	0.4	0.2	.	.	0.2	0.2	.	.
92	ARABELLA MUTANS	.	.	.	.	.	.	.	.	0.6	0.2
92	NEREIS SUCCINEA	.	.	.	.	.	.	0.4	0.4	0.2	0.2
92	NEREIS SP.	.	.	.	.	0.4	0.2	0.2	0.2	.	.
116	UPOGEBIA AFFINIS	.	.	.	.	0.2	0.2	0.2	0.2	.	.
116	EUCERAMUS PRAELONGUS	.	.	.	.	0.2	0.2	0.2	0.2	.	.
116	PAGURUS LONGICARPUS	0.2	0.2	.	.	0.2	0.2	.	.	.	.
116	OVALIPES STEPHENSONI	.	.	.	.	0.2	0.2	0.2	0.2	.	.
116	UPOGEBIA SP.	.	.	0.2	0.2	.	.	0.2	0.2	.	.
116	BRACHYURA	.	.	.	.	0.4	0.2	.	.	.	.
116	MICROPROTOPUS RANEYI	0.2	0.2	.	.	0.2	0.2	.	.	.	.
116	CERAPUS TUBULARIS	.	.	0.4	0.4	.	.	.	.	.	.
116	EDOTEA MONTOSA	0.4	0.4	.	.	.	.	.	.	.	.
116	COROPHIUM SP.	.	.	.	.	0.2	0.2	.	.	0.2	0.2
116	BOWMANIELLA FLORIDANA	.	.	0.2	0.2	.	.	.	.	0.2	0.2
116	TURBELLARIA	.	.	.	.	0.2	0.2	.	.	0.2	0.2
116	CUCUMARIA PULCHERRIMA	.	.	.	.	.	.	.	.	0.4	0.2
116	GLOTTIDIA PYRAMIDATA	.	.	.	.	.	.	.	.	0.4	0.2
116	NUCULA PROXIMA	0.4	0.2	.	.	.	.	.	.	.	.
116	LYONSIA HYALINA	.	.	.	.	.	.	.	.	0.4	0.2
116	TURBONILLA SP. B	.	.	.	.	0.2	0.2	.	.	0.2	0.2
116	MAGELONA SP. A	.	.	.	.	0.4	0.4	.	.	.	.
116	SABELLARIIDAE	.	.	.	.	0.4	0.4	.	.	.	.
116	MEIODORVILLEA SP. A	.	.	.	.	.	.	.	.	0.4	0.4
116	MYRIOWENIA SP. A	.	.	.	.	0.4	0.4	.	.	.	.
116	SCOLOPLOS RUBRA	.	.	0.2	0.2	.	.	.	.	0.2	0.2
116	GLYCERA SP.	.	.	.	.	.	.	0.4	0.2	.	.
116	GLYCERA CAPITATA	.	.	0.4	0.2	.	.	.	.	.	.
116	CISTENIDES GOULDII	.	.	.	.	.	.	0.4	0.2	.	.

Appendix B. (Continued)

DISPOSAL AREA, SUMMER SAMPLES

RANK	SPECIES	DS03		DS06		DS08		DS10		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
116	SYNELMIS ALBINI	.	.	.	.	.	.	.	.	0.4	0.4
116	CAPITELLA CAPITATA	.	.	0.4	0.4	.	.	.	.	.	.
116	EXOGONE DISPAR	.	.	.	.	0.2	0.2	0.2	0.2	.	.
116	HAPLOSCOLOPLOS FRAGILIS	.	.	0.2	0.2	0.2	0.2	.	.	.	.
116	THARYX SP.	.	.	.	.	.	.	0.4	0.2	.	.
116	ARMANDIA MACULATA	.	.	.	.	.	.	0.4	0.2	.	.
116	HESIONIDAE	0.2	0.2	0.2	0.2	.	.	.	.	.	.
116	CIRRATULIDAE	.	.	.	.	.	.	.	.	0.4	0.2
165	LATREUTES PARVULUS	.	.	.	.	.	.	.	.	0.2	0.2
165	OGYRIDES ALPHAEROSTRIS	.	.	.	.	0.2	0.2	.	.	.	.
165	OSACHILA TUBEROSA	.	.	.	.	0.2	0.2	.	.	.	.
165	PORTUNUS GIBBESII	.	.	.	.	0.2	0.2	.	.	.	.
165	PAGURUS SP.	.	.	.	.	.	.	.	.	0.2	0.2
165	PROCESSA HEMPHILLI	0.2	0.2	.	.	.	.	.	.	.	.
165	SQUILLA EMPUSA	.	.	.	.	0.2	0.2	.	.	.	.
165	SYNCHELIDIUM AMERICANUM	.	.	.	.	0.2	0.2	.	.	.	.
165	BATHYPOREIA PARKERI	.	.	0.2	0.2	.	.	.	.	.	.
165	LEMBOS UNICORNIS	.	.	.	.	.	.	.	.	0.2	0.2
165	ACANTHOHAUSTORIUS INTERMEDIUS	.	.	.	.	0.2	0.2	.	.	.	.
165	PHOTIS PUGNATOR	0.2	0.2	.	.	.	.	.	.	.	.
165	MYSIDACEA	.	.	.	.	.	.	.	.	0.2	0.2
165	APANTHURA MAGNIFICA	.	.	.	.	.	.	.	.	0.2	0.2
165	ANOPLODACTYLUS PETIOLATUS	.	.	.	.	.	.	.	.	0.2	0.2
165	OPHIUROIDEA	.	.	.	.	.	.	.	.	0.2	0.2
165	HOLOTHUROIDEA	0.2	0.2	.	.	.	.	.	.	.	.
165	CUPULADRIIDAE A	.	.	.	.	.	.	.	.	0.2	0.2
165	TELLINA TEXANA	.	.	0.2	0.2	.	.	.	.	.	.
165	MACOMINAE	.	.	.	.	.	.	0.2	0.2	.	.
165	CREPIDULA SP.	.	.	.	.	0.2	0.2	.	.	.	.
165	OSTREA EQUESTRIS	.	.	.	.	.	.	.	.	0.2	0.2
165	CHAMA MACEROPHYLLA	.	.	.	.	.	.	.	.	0.2	0.2
165	LIMA PELLUCIDA	.	.	.	.	.	.	.	.	0.2	0.2
165	PELECYPODA S	.	.	.	.	0.2	0.2	.	.	.	.
165	MULINIA LATERALIS	0.2	0.2	.	.	.	.	.	.	.	.
165	TURBONILLA SP.	.	.	.	.	.	.	.	.	0.2	0.2
165	TURBONILLA SP. D	.	.	.	.	.	.	.	.	0.2	0.2
165	TEREBRA CONCAVA	.	.	.	.	0.2	0.2	.	.	.	.
165	TELLINIDAE	.	.	.	.	.	.	.	.	0.2	0.2
165	AMAEANA TRILOBATA	.	.	.	.	0.2	0.2	.	.	.	.
165	SYLLIS GRACILIS	.	.	.	.	.	.	.	.	0.2	0.2
165	MAGELONA SP. D	.	.	0.2	0.2	.	.	.	.	.	.
165	AUTOLYTUS SP.	.	.	.	.	0.2	0.2	.	.	.	.
165	PRIONOSPIO SP. A	.	.	0.2	0.2	.	.	.	.	.	.
165	OPHELIIDAE	.	.	.	.	.	.	.	.	0.2	0.2
165	NEREIS FALSA	.	.	.	.	0.2	0.2	.	.	.	.
165	SPHAEROSYLLIS ACICULATA	.	.	.	.	.	.	.	.	0.2	0.2
165	ONUPHIDAE	.	.	0.2	0.2	.	.	.	.	.	.
165	LUMBRINERIS LATREILLI	.	.	.	.	.	.	.	.	0.2	0.2
165	PISTA CRISTATA	.	.	.	.	0.2	0.2	.	.	.	.
165	CIRROPHORUS BRANCHIATUS	.	.	.	.	.	.	.	.	0.2	0.2
165	ARICIDEA CERRUTII	.	.	.	.	.	.	0.2	0.2	.	.
165	DISPIO UNCINATA	.	.	0.2	0.2	.	.	.	.	.	.
165	SCOLELEPIS SQUAMATA	.	.	.	.	.	.	0.2	0.2	.	.
165	SCOLOPLOS SP.	.	.	.	.	0.2	0.2	.	.	.	.
165	PHYLLODOCE MUCOSA	.	.	.	.	.	.	0.2	0.2	.	.
165	ARABELLA IRICOLOR	.	.	.	.	0.2	0.2	.	.	.	.
165	LEPIDONOTUS SUBLEVIS	.	.	.	.	.	.	0.2	0.2	.	.
165	PODARKE OBSCURA	0.2	0.2	.	.	.	.	.	.	.	.
165	MAGELONA PAPILLICORNIS	.	.	.	.	0.2	0.2	.	.	.	.
165	POECILOCHAETUS SP.	.	.	.	.	.	.	.	.	0.2	0.2
165	SPIONIDAE	.	.	.	.	.	.	.	.	0.2	0.2
165	SPIONIDAE A	0.2	0.2	.	.	.	.	.	.	.	.

Appendix 8. (Continued)

DISPOSAL AREA, SUMMER SAMPLES

RANK	SPECIES	DS03		DS06		DS08		DS10		CS13	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
165	ORBINIIDAE	.	.	.	.	0.2	0.2	.	.	.	.
165	THARYX ANNULOSUS	.	.	.	.	.	.	0.2	0.2	.	.
165	POLYDORA SP. B	.	.	.	.	0.2	0.2	.	.	.	.
165	POLYDORA SP. G	.	.	.	.	.	.	0.2	0.2	.	.
165	GONIADIDAE	.	.	.	.	.	.	0.2	0.2	.	.
165	BRANIA CLAVATA	.	.	.	.	.	.	0.2	0.2	.	.
165	PHYLLODOCE ARENAE	.	.	.	.	.	.	0.2	0.2	.	.
165	POLYDORA CAECA	.	.	.	.	.	.	0.2	0.2	.	.
165	PRIONOSPIO CRISTATA	.	.	.	.	0.2	0.2	.	.	.	.
165	SIGALION ARENICOLA	.	.	.	.	.	.	.	.	0.2	0.2
165	TRAVISIA PARVA	.	.	0.2	0.2	.	.	.	.	.	.

Appendix 9. Overall ranked abundance of macroinvertebrates collected during winter at the "down current" site. Mean density (number per 0.1 m^2) and standard error of the mean at each station is indicated.

DOWN CURRENT AREA, WINTER SAMPLES

RANK	SPECIES	DC01		DC02		DC03	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
1	ENSIS DIRECTUS	112.4	25.2	28.4	4.8	6.8	0.8
2	POLYGORDIIDAE A	25.4	16.4	1.4	0.4	.	.
3	NEMATODA	11.2	6.4	0.2	0.2	1.0	0.8
4	NEMERTINEA	3.4	1.5	0.4	0.2	1.2	0.7
5	POLYCIRRUS EXIMIUS	0.2	0.2	3.4	0.7	.	.
6	NEPHTYS PICTA	1.6	0.4	1.4	0.7	0.4	0.2
7	SABELLARIA VULGARIS	.	.	3.0	1.6	.	.
8	ANCINUS DEPRESSUS	.	.	1.2	0.7	1.6	0.8
9	GLYCERA SP. A	2.0	0.5	.	.	.	.
9	NERINIDES UNIDENTATA	0.4	0.2	1.4	0.4	0.2	0.2
11	CRASSINELLA MARTINICENSIS	.	.	1.8	1.8	.	.
12	HEMIPODUS ROSEUS	1.0	0.5	0.6	0.4	.	.
12	MALDANIDAE	1.2	1.2	0.4	0.2	.	.
16	PYURA VITTATA	.	.	1.2	0.7	.	.
16	ACANTHOHAUSTORIUS MILLSI	0.8	0.4	0.4	0.2	.	.
16	EUDEVENOPUS HONDURANUS	0.2	0.2	1.0	0.6	.	.
16	GLYCERA OXYCEPHALA	0.2	0.2	1.0	0.3	.	.
16	OLIGOCHAETA	1.0	0.5	.	.	0.2	0.2
16	MEDIOMASTUS CALIFORNIENSIS	1.2	0.6	.	.	.	.
23	MELLITA QUINQUESPERFORATA	.	.	0.6	0.4	0.4	0.2
23	AMPHIODIA PULCHELLA	0.6	0.4	0.4	0.4	.	.
23	PELECYPODA B	0.2	0.2	0.6	0.4	0.2	0.2
23	ASPIDOSIPHON GOSNOLDI	.	.	1.0	0.5	.	.
23	OPHELIA DENTICULATA	0.4	0.4	0.4	0.2	0.2	0.2
23	MAGELONA SP.	0.8	0.6	0.2	0.2	.	.
23	SPIOPHANES BOMBYX	0.8	0.6	0.2	0.2	.	.
23	GLYCERA DIBRANCHIATA	0.8	0.4	0.2	0.2	.	.
28	PROTOHAUSTORIUS DEICHMANNAE	.	.	.	.	0.8	0.6
28	MAGELONA ROSEA	0.8	0.2	.	.	.	.
31	METHARPINIA FLORIDANA	0.4	0.2	0.2	0.2	.	.
31	ACANTHOHAUSTORIUS INTERMEDIUS	.	.	0.6	0.4	.	.
31	ERICHTHONIUS BRASILIENSIS	.	.	0.2	0.2	0.4	0.2
31	TELLINA TEXANA	.	.	.	.	0.6	0.6
36	RATEA CATHARINENSIS	.	.	0.4	0.4	.	.
36	NATICA PUSILLA	0.2	0.2	0.2	0.2	.	.
36	PELECYPODA A	0.4	0.4	.	.	.	.
36	CRASSINELLA LUNULATA	0.2	0.2	0.2	0.2	.	.
36	EXOGONE DISPAR	.	.	0.4	0.2	.	.
36	CAULLERIELLA KILLARIENSIS	0.4	0.2	.	.	.	.
57	PAGURUS LONGICARPUS	.	.	0.2	0.2	.	.
57	DISSODACTYLUS MELLITAE	.	.	.	.	0.2	0.2
57	PAGURIDAE	.	.	0.2	0.2	.	.
57	LILJEBORGIA SP. A	.	.	0.2	0.2	.	.
57	PARAHAUSTORIUS LONGIMERUS	.	.	.	.	0.2	0.2
57	OSTRACODA	.	.	.	.	0.2	0.2
57	UNCIOLA SERRATA	0.2	0.2	.	.	.	.
57	PARACAPRELLA TENUIS	.	.	.	.	0.2	0.2
57	HAUSTORIIDAE	.	.	.	.	0.2	0.2
57	TIRON TRIOCELLATUS	0.2	0.2	.	.	.	.
57	OPHIUROIDEA	.	.	0.2	0.2	.	.
57	INVERTEBRATA E	0.2	0.2	.	.	.	.
57	PARVANACHIS OBESA	0.2	0.2	.	.	.	.
57	NUCULA PROXIMA	.	.	0.2	0.2	.	.
57	BRACHIDONTES EXUSTUS	.	.	0.2	0.2	.	.
57	PETRICOLA PHOLADIFORMIS	.	.	.	.	0.2	0.2
57	CREPIDULA FORNICATA	.	.	0.2	0.2	.	.
57	ARCIDAE A	.	.	0.2	0.2	.	.
57	TELLINIDAE	.	.	0.2	0.2	.	.
57	HYDROIDES UNCINATA	.	.	0.2	0.2	.	.
57	CIRRIFORMIA GRANDIS	.	.	0.2	0.2	.	.
57	PARAPIONOSYLLIS SP.	0.2	0.2	.	.	.	.
57	BHAWANIA GOODEI	.	.	0.2	0.2	.	.

Appendix 9. (Continued)

DOWN CURRENT AREA, WINTER SAMPLES

RANK	SPECIES	DC01		DC02		DC03	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
57	STREPTOSYLLIS SP.	.	.	0.2	0.2	.	.
57	PSEUDEURYTHOE AMBIGUA	0.2	0.2	.	.	.	.
57	NEPHTYS INCISA	.	.	0.2	0.2	.	.
57	ANCISTROSYLLIS HARTMANAE	0.2	0.2	.	.	.	.
57	SCOLOPLOS SP.	0.2	0.2	.	.	.	.
57	GLYCERIDAE	0.2	0.2	.	.	.	.
57	ONUPHIS EREMITA	.	.	.	.	0.2	0.2
57	PODARKE OBSCURA	.	.	0.2	0.2	.	.
57	CAPITELLIDAE	.	.	0.2	0.2	.	.
57	GONIADIDAE	0.2	0.2	.	.	.	.
57	POLYDORA CAECA	.	.	0.2	0.2	.	.
57	NEPHTYIDAE	.	.	.	.	0.2	0.2

Appendix 10. Overall ranked abundance of macroinvertebrates collected during summer at the "down current" site. Mean density (number per 0.1 m^2) and standard error of the mean at each station is indicated.

DOWN CURRENT AREA, SUMMER SAMPLES

RANK	SPECIES	DC01		DC02		DC03	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
1	CUPULADRIA DOMA	0.2	0.2	49.2	8.6	.	.
2	ENSIS DIRECTUS	12.0	3.3	0.4	0.4	.	.
3	PYURA VITTATA	1.0	0.4	10.4	2.1	0.2	0.2
4	PARAPRIONOSPIO PINNATA	0.2	0.2	.	.	10.4	1.3
5	CRASSINELLA MARTINICENSIS	4.2	0.8	0.6	0.4	0.4	0.2
6	MAGELONA PHYLLISAE	5.0	1.2	.	.	.	.
6	OLIGOCHAETA	.	.	4.6	1.2	0.4	0.4
8	SABELLARIA VULGARIS	0.4	0.2	2.4	1.4	1.6	1.4
9	NEPHTYS PICTA	3.6	1.3	0.6	0.4	.	.
10	NEMERTINEA	3.0	0.5	1.2	0.4	.	.
11	NATICA CATHARINENSIS	.	.	0.8	0.6	2.6	2.1
11	MULINIA LATERALIS	0.2	0.2	.	.	3.2	1.1
13	PAGURUS HENDERSONI	0.2	0.2	0.2	0.2	2.6	1.5
13	MEDIOMASTUS CALIFORNIENSIS	.	.	2.2	0.9	0.8	0.4
15	ANCINUS DEPRESSUS	0.2	0.2	0.2	0.2	2.0	1.1
15	HEMIPODUS ROSEUS	.	.	2.4	0.6	.	.
17	CERAPUS TUBULARIS	0.4	0.4	.	.	1.8	1.6
18	SPIOPHANES BOMBYX	0.2	0.2	1.8	0.6	.	.
19	MAGELONA SP. A	1.8	0.5	.	.	.	.
20	PLEUROMERIS TRIDENTATA	0.2	0.2	1.4	0.6	.	.
23	AMPHIODIA PULCHELLA	.	.	1.4	1.2	.	.
23	HEMICHORDATA A	.	.	.	.	1.4	0.7
23	POLYGORDIIDAE A	1.2	0.4	0.2	0.2	.	.
23	ANCISTROSYLLIS HARTMANAE	.	.	1.4	0.9	.	.
23	AMPHARETE AMERICANA	.	.	.	.	1.4	1.4
27	PAGURUS LONGICARPUS	.	.	.	.	1.2	0.6
27	MELLITA QUINQUESPERFORATA	0.8	0.5	0.4	0.2	.	.
27	CREPIDULA PLANA	0.4	0.4	0.8	0.8	.	.
31	AUTOMATE EVERMANNI	0.4	0.4	0.6	0.4	.	.
31	ACANTHOHAUSTORIUS MILLSI	.	.	1.0	0.4	.	.
31	NEMATODA	.	.	1.0	1.0	.	.
31	ASPIDOSIPHON GOSNOLDI	.	.	1.0	0.3	.	.
31	OPHELIA DENTICULATA	.	.	1.0	0.5	.	.
31	MAGELONA ROSEA	1.0	0.5	.	.	.	.
37	ACTINIARIA	0.4	0.2	0.4	0.4	.	.
37	GONIADA LITTOREA	0.8	0.4	.	.	.	.
37	CIRROPHORUS LYRIFORMIS	.	.	0.8	0.4	.	.
37	GLYCERA OXYCEPHALA	.	.	0.8	0.4	.	.
37	POLYCIRRUS EXIMIUS	.	.	0.8	0.4	.	.
37	HAPLOSCOLOPLOS FRAGILIS	0.8	0.4	.	.	.	.
46	TRACHYPENAEUS CONSTRICTUS	.	.	0.4	0.2	0.2	0.2
46	PINNIXA SP.	0.2	0.2	0.4	0.4	.	.
46	PARVILUCINA MULTILINEATA	0.6	0.4	.	.	.	.
46	PELECYPODA B	0.4	0.2	0.2	0.2	.	.
46	PELECYPODA C	.	.	0.6	0.4	.	.
46	CRASSINELLA LUNULATA	0.6	0.2	.	.	.	.
46	PARAPIONOSYLLIS SP. A	.	.	0.6	0.2	.	.
46	THARYX MARIONI	.	.	0.6	0.2	.	.
46	PRIONOSPIO FALLAX	.	.	0.6	0.4	.	.
46	GLYCERA DIBRANCHIATA	0.4	0.4	0.2	0.2	.	.
46	NOTOCIRRUS SPINIFERUS	0.6	0.4	.	.	.	.
63	OGYRIDES ALPHAEROSTRIS	.	.	.	.	0.4	0.2
63	UPOGEBIA AFFINIS	.	.	0.4	0.2	.	.
63	PAGURUS POLLICARIS	0.2	0.2	0.2	0.2	.	.
63	DISSODACTYLUS MELLITAE	0.2	0.2	0.2	0.2	.	.
63	PROMYSIS ATLANTICA	0.4	0.2	.	.	.	.
63	METHARPINIA FLORIDANA	.	.	0.4	0.2	.	.
63	UNCIOLA SERRATA	.	.	0.4	0.2	.	.
63	OXYUROSTYLIS SMITHI	0.2	0.2	.	.	0.2	0.2
63	MYSIDOPSIS BIGELOWI	0.2	0.2	0.2	0.2	.	.
63	COROPHIUM SP.	.	.	0.4	0.2	.	.
63	COROPHIUM SP. C	0.2	0.2	.	.	0.2	0.2

Appendix 10. (Continued)

DOWN CURRENT AREA, SUMMER SAMPLES

RANK	SPECIES	DC01		DC02		DC03	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
63	EUDEVENOPUS HONDURANUS	.	.	0.4	0.2	.	.
63	PELECYPODA	0.2	0.2	0.2	0.2	.	.
63	CREPIDULA FORNICATA	.	.	0.4	0.4	.	.
63	SCOLOPLOS RUBRA	.	.	0.4	0.2	.	.
63	AGLAOPHAMUS VERRILLI	0.4	0.2	.	.	.	.
63	DISPIO UNCINATA	0.4	0.2	.	.	.	.
63	SIGAMBRA TENTACULATA	0.4	0.2	.	.	.	.
63	TRAVISIA SP. C	.	.	0.4	0.4	.	.
63	GLYCINDE SOLITARIA	.	.	.	.	0.4	0.2
63	DIOPATRA CUPREA	.	.	0.2	0.2	0.2	0.2
63	MAGELONA PAPILLICORNIS	0.4	0.2	.	.	.	.
63	SPIO PETTIBONEAE	.	.	0.4	0.2	.	.
97	BRANCHIOSTOMA CARIBAEUM	.	.	0.2	0.2	.	.
97	LEPTOCHELA SERRATORBITA	.	.	.	.	0.2	0.2
97	LATREUTES PARVULUS	.	.	.	.	0.2	0.2
97	PORCELLANA SAYANA	.	.	.	.	0.2	0.2
97	PORTUNUS GIBBESII	.	.	.	.	0.2	0.2
97	PENAEIDAE	.	.	.	.	0.2	0.2
97	PINNOTHERES SP.	.	.	0.2	0.2	.	.
97	ALPHEUS SP.	.	.	.	.	0.2	0.2
97	RHEPOXYNIUS EPISTOMUS	0.2	0.2	.	.	.	.
97	ACANTHOHAUSTORIUS INTERMEDIUS	0.2	0.2	.	.	.	.
97	MYSIDACEA	.	.	.	.	0.2	0.2
97	BOWMANIELLA SP.	.	.	0.2	0.2	.	.
97	MICROPROTOPUS SHOEMAKERI	0.2	0.2	.	.	.	.
97	MICROPROTOPUS SP.	.	.	.	.	0.2	0.2
97	BOWMANIELLA BRASILIENSIS	.	.	0.2	0.2	.	.
97	TIRON TRIOCELLATUS	.	.	0.2	0.2	.	.
97	OLIVELLA MUTICA	.	.	0.2	0.2	.	.
97	NATICA PUSILLA	0.2	0.2	.	.	.	.
97	TELLINA PROBRINA	.	.	0.2	0.2	.	.
97	ABRA AEQUALIS	.	.	0.2	0.2	.	.
97	TEREBRA CONCAVA	0.2	0.2	.	.	.	.
97	TEREBRA DISLOCATA	.	.	0.2	0.2	.	.
97	ECHIURIDA	.	.	0.2	0.2	.	.
97	ONUPHIS SP.	.	.	0.2	0.2	.	.
97	ONUPHIS SP. A	.	.	0.2	0.2	.	.
97	ACROCIRRIDAE A	.	.	0.2	0.2	.	.
97	GLYCERA SP. A	0.2	0.2	.	.	.	.
97	LUMBRINERIS LATREILLI	0.2	0.2	.	.	.	.
97	POLYDORA COMMENSALIS	0.2	0.2	.	.	.	.
97	NEREIS SUCCINEA	0.2	0.2	.	.	.	.
97	ONUPHIS EREMITA	0.2	0.2	.	.	.	.
97	PODARKE OBSCURA	.	.	0.2	0.2	.	.
97	POLYDORA LIGNI	.	.	0.2	0.2	.	.
97	POECILOCHAETUS SP.	.	.	0.2	0.2	.	.
97	HESIONIDAE	.	.	0.2	0.2	.	.
97	THARYX ANNULOSUS	.	.	0.2	0.2	.	.
97	MALDANIDAE	.	.	0.2	0.2	.	.
97	POLYDORA SP.	0.2	0.2	.	.	.	.
97	SYLLIDAE	.	.	0.2	0.2	.	.
97	BRANIA CLAVATA	.	.	0.2	0.2	.	.
97	EULALIA SANGUINEA	.	.	0.2	0.2	.	.
97	POLYDORA CAECA	.	.	0.2	0.2	.	.
97	TRAVISIA SP. B	.	.	0.2	0.2	.	.
97	SCHISTOMERINGOS CAECA	.	.	0.2	0.2	.	.
97	LUMBRINERIDES ACUTA	.	.	0.2	0.2	.	.

Appendix 11. Species diversity and faunal density of grab samples collected in the study area. The units for values of H' are bits.

STATION	DIVERSITY (H')	EVENNESS (J')	RICHNESS (SR)	NUMBER OF INDIVIDUALS/0.5 m^2	NUMBER OF SPECIES
			WINTER		
CS02	3.8	0.6	11.2	832	76
CS04	4.7	0.7	12.0	794	81
CS09	5.0	0.8	13.4	559	86
CS10	5.6	0.7	23.9	3120	193
CS13	4.5	0.7	15.7	1252	113
DS03	3.4	0.7	6.3	192	34
DS06	3.2	0.6	6.8	472	43
DS09	4.2	0.7	12.0	571	77
DS11	1.4	0.3	5.0	736	34
DS13	3.4	0.6	10.3	741	69
DC01	2.0	0.4	5.3	851	37
DC02	3.4	0.6	8.3	282	48
DC03	3.2	0.7	4.6	78	21
			SUMMER		
CS02	3.9	0.6	10.5	500	66
CS05	4.3	0.7	11.1	426	68
CS09	4.9	0.8	12.5	371	75
CS11	5.8	0.8	19.3	754	129
CS13	5.2	0.7	17.5	1410	128
DS03	3.0	0.6	6.7	219	37
DS06	3.4	0.6	10.6	721	71
DS08	5.8	0.9	16.8	454	104
DS10	4.6	0.7	12.8	778	86
DS13	3.1	0.5	12.9	2171	100
DC01	4.3	0.8	9.3	234	52
DC02	3.7	0.6	12.2	518	77
DC03	3.7	0.8	5.3	166	28

Appendix 12. Tissue sample analysis of <u>Busycon</u> <u>carica</u> from Georgetown DMDS area. (CH - channel, CS - control, DS - disposal, DC - down current)

	CS	DS	DC	SPIKE CS	SPIKE DC
PCBs µg/g	ND	ND	ND	1254 PCB - 100.0%	
α-BHC µg/g	ND	ND	ND		
lindane µg/g	ND	ND	ND	59.8%	
heptachlor µg/g	ND	ND	ND		
B-BHC µg/g	ND	ND	ND		
aldrin µg/g	ND	ND	ND		
heptachlor epoxide µg/g	ND	ND	ND		
P, P^1 - DDE µg/g	ND	ND	ND		
O, P^1 - DDD µg/g	ND	ND	ND		
O, P^1 - DDT µg/g	ND	ND	ND		
chlordane µg/g	ND	ND	ND		
dieldrin µg/g	ND	ND	ND		
endrin µg/g	ND	ND	ND	100.0%	
P, P^1 - DDD µg/g	ND	ND	ND		
P, P^1 - DDT µg/g	ND	ND	ND		
mirex µg/g	ND	ND	ND		
methoxychlor µg/g	ND	ND	ND		
toxaphene µg/g	ND	ND	ND		
		Methoxychlor		134.9%	
Wet wt. of sample extracted µg/g	50.6597	51.8103	50.8697		C^{18} 58.3% Recovery C^{19} 48.7% Recovery C^{20} 53.1% Recovery C^{22} 41.7% Recovery
Total resolved Hydrocarbons by GC µg/g	ND	ND	ND		
Total Unresolved Hydrocarbons by GC µg/g	ND	ND	ND		
Sum of the n-Alkanes µg/g	ND	ND	ND		

Appendix 12. (Continued)

	CS	DS	DC
Sum of the even n-Alkanes µg/g	ND	ND	ND
Sum of the odd n-Alkanes µg/g	ND	ND	ND
Unresolved Hydrocarbons/Resolved Hydrocarbons µg/g	ND	ND	ND
Pristane + Phytane/ n-Alkanes µg/g	ND	ND	ND
Odd n-Alkanes/ Even n-Alkanes µg/g	ND	ND	ND
Pristane/n-17 µg/g	ND	ND	ND
Phytane/n-18 µg/g	ND	ND	ND
Pristane/Phytane µ g/g	ND	ND	ND
n-Alkanes/Branched Hydrocarbons µg/g	ND	ND	ND
Cadmium µg/g	< 0.1	< 0.1	< 0.1
Arsenic µg/g	1.67	2.34	1.92
Chromium µg/g	< 0.1	< 0.1	< 0.1
Nickel µg/g	< 0.5	< 0.5	< 0.5
Copper µg/g	6.15	9.65	7.09
Lead µg/g	< 0.5	< 0.5	< 0.5
Mercury µg/kg	< 1.0	< 1.0	< 1.0
Zinc µg/g	52.28	53.61	50.77

ND - Not Detected; Detection Limit is 50 ppb.